EVALUATION OF FEEDSTUFFS AND THE METABOLISABLE ENERGY AND AMINO ACID REQUIREMENTS FOR MAINTENANCE AND GROWTH IN OSTRICHES (STRUTHIO CAMELUS)

BY

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"DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis project is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

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SUMMARY

Differences in the digestion and metabolism of ostriches and poultry, require the assessment of nutritional values (especially ME values) of various ingredients to establish a new system for ostrich feed evaluation. These findings are a prerequisite for the determination of nutrient requirements and efficient diet formulations.

A number of comparative studies between ostriches and adult roosters were conducted with respect to true and apparent metabolisable energy, corrected for nitrogen retention (TME_n and AME_n) of common ingredients used in diets for ostriches and poultry. Results were obtained by balance method with continuous feeding and total excreta collection. Results obtained for mature ostriches were then compared to those calculated for younger birds (6 months of age). AME_n values were determined according to the replacement method, while TME_n values were calculated, using the regression method.

The theory of ME determinations and the accuracy of determined TME_n values of ingredients for ostriches and roosters were evaluated by comparing theoretical and determined TME_n values of an experimental diet, comprising various ingredients. Experimental evidence was produced to confirm the suitability of the method used for determining ME in ostriches, for measuring amino acid availabilities. Hence a comparative study was conducted between ostriches and roosters with respect to the true and apparent availabilities of amino acids in an experimental diet.

In a response study, nutrient (energy, amino acids, protein, lipid and ash) retentions in feathers, hides, legs and carcasses, was separetly measured by means of comparative slaughter technique. Requirements for maintenance and utilisation efficiencies were established. The potential growth of a flock of ostriches, representative of Oudtshoorn birds, were estimated according to the Gompertz Model. Potential growth, feed consumption figures, carcass characteristics and utilisation efficiencies, were then used to compute dietary requirements for the experimental group of birds (7 months of age) and these results were extrapolated to assess dietary requirements for ostriches from dayold to maturity (day 600).

OPSOMMING

Verterings - en metabolisme verskille tussen volstruise en pluimvee, noodsaak die evaluering van verskeie grondstowwe vir die ontwikkeling van 'n grondstof-evaluerings-sisteem vir volstruise. Die resultate is noodsaaklik vir die bepaling van voedingsbehoeftes en doeltreffende rantsoen-formulerings.

Verskeie vergelykende studies tussen volstruise en pluimvee is onderneem ten opsigte vir die bepaling van ware en skynbare metaboliseerbare energie waardes, gekorrigeer vir stikstof-retensie (WME_n en SME_n), vir algemene grondstowwe. Daar is gebruik gemaak van die balans-metode met aaneenlopende voeding en ekskreta-versameling. Resultate wat vir volwasse volstruise verkry is, is ook vergelyk met die van jonger kuikens (6 maande). SME_n waardes is bereken volgens die vervangings-tegniek, terwyl WME_n-waardes bereken is volgens die regressie-metode.

Die teorie en akkuraatheid van bepaalde WME_n waardes is bevestig deur 'n vergelykende studie tussen teoretiese en bepaalde waardes van 'n eksperimentele rantsoen vir beide volstruise en pluimvee. Die bruikbaarheid van die balans-tegniek vir energie-bepalings, is ook bevestig vir die bepaling aminosuur-beskikbaarheid by volstruise.

Energie-, proteïen-, aminosuur-, vet- en as-retensies in vere, vel, bene en karkas, is met behulp van 'n vergelykende slagproef in volstruise gemeet. Onderhouds-behoeftes en benuttingsdoeltreffendhede kon gevolglik beraam word. Groeikurwes vir 'n verteenwoordigende monster Oudsthoorn-volstruise is ook bepaal volgens die Gompertz-model. Potensiële groei, voerinnames, karkas-eienskappe en benuttingsdoeltreffendhede is gebruik vir die berekening van rantsoen-spesifikasies vir 'n eksperimentele groep kuikens (7 maande) en die gegewens is ge-ekstrapoleer om rantsoen-spesifikasies vir volstruise te beraam van dagoud tot volwassenheid (600 dae).

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CHAPTER 1

INTRODUCTION

Although ostrich farming is a well established industry in South Africa, scientific information on nutritional values of ingredients and dietary requirements is severely limiting. Nutritional results obtained for poultry, were extrapolated to develop nutrition strategies for ostriches, which often resulted in the application of unrealistic values. This became evident from various nutrition-related problems encountered by commercial ostrich farmers, raising birds in feedlots on concentrated diets.

To enhance the profitability of ostriches as meat, hide and feather producers, requires accurate nutritional evaluation of feed ingredients. The reasons are (Oldham and Emmans, 1990):

1. To determine the extent to which a feed ingredient will promote growth and production in a bird and their provision of essential nutrients.
2. To measure the utilisation of various ingredients and the extent to which one ingredient can substitute another to promote growth and production.
3. To be able to assess animal performance through nutrition

Metabolisable energy (ME) has become the generally excepted energy form for expressing feed values and energy requirements in poultry (Miller, 1974). The metabolisable energy system describes the difference between gross energy intake and energy excreted as faeces and urine when feed is consumed. Swart, Mackie and Hayes (1993a) observed that the large chambers in the hindgut of ostriches are suitable for fermentative digestion, due to its large capacity, neutral pH and high concentrations of volatile fatty acids. Substantially extended retention times were also measured in ostriches as opposed to poultry, ensuring extended exposure to microbial digestion in ostriches. Swart, Mackie and Hayes (1993a) concluded that the production of volatile fatty acids could make a substantial contribution to the energy requirements of ostriches. Improved ME values were observed for an experimental diet fed to ostriches as opposed to theoretical values derived from poultry (Swart, Mackie and Hayes, 1993b). It was concluded that differences in the digestion and metabolism between ostriches and poultry require the assessment of nutritional values (especially ME values) of various ingredients to establish a new system for ostrich feed evaluation. These findings are a prerequisite for the determination of nutrient requirements and efficient diet formulations.

A number of comparative studies between ostriches and adult roosters were conducted with respect to true and apparent metabolisable energy, corrected for nitrogen retention (TME_n and AME_n) of common ingredients used in diets for ostriches and poultry (Chapter 3 to Chapter 10). Results were obtained by balance method with continuous feeding and total excreta collection. Excreta collection harnesses were

designed with collection bags and birds were housed in wooden metabolism cages (Chapter 3). Results obtained for mature ostriches were then compared to those calculated for younger birds (6 months of age), (Chapter 6). Samples from the same batches of ingredients tested in ostriches, were simultaneous evaluated in roosters according to the DSQ-method of Du Preez, Duckitt and Paulse (1986). AME_n values were determined according to the replacement method (Hill, Anderson, Renner and Carew, 1960), while TME_n values were calculated, using the regression method.

In least cost formulation where an ME value is assigned to an ingredient independent of the nature of the diet, it is assumed that all values should be additive (Miller, 1974). This theory and the accuracy of determined TME_n values of ingredients for ostriches and roosters were evaluated by comparing theoretical and determined TME_n values of an experimental diet, comprising various ingredients (Chapter 11). Experimental evidence was produced to confirm the suitability of the method used for determining ME in ostriches, for measuring amino acid availabilities. Hence a comparative study was conducted between ostriches and roosters with respect to the true and apparent availabilities of amino acids in an experimental diet (Chapter 12).

The question on utilisation efficiency of dietary nutrients remained and estimates were required for the establishment of dietary requirements. In a response study, nutrient (energy, amino acids, protein, lipid and ash) retentions in feathers, hides, legs and carcasses, was separetly measured by means of comparative slaughter technique (Chapter13). Requirements for maintenance and utilisation efficiencies were established.

The potential growth of a flock of ostriches, representative of Oudtshoorn birds, were estimated according to the Gompertz Model (Emmans, 1989). Potential growth, feed consumption figures, carcass characteristics and utilisation efficiencies, were used to compute dietary requirements for the experimental group of birds (7 months of age) and these results were extrapolated to assess dietary requirements for ostriches from dayold to maturity (day 600).

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CHAPTER 2

THE METHODOLOGY BEHIND THE CALCULATION OF THE TRUE (TME) AND APPARENT METABOLISABLE ENERGY (AME) VALUES OF INGREDIENTS.

The metabolisable energy system can be divided into two categories namely apparent- (AME) and true metabolisable energy (TME). AME is the term that describes the difference between gross energy (GE) intake and energy excreted as faeces and urine when feed is consumed (Harris, 1966). Thus:

$$AME = \frac{\text{GE intake, MJ - GE excreted, MJ}}{\text{Feed intake, kg}} \quad \text{where} \qquad [1]$$

$$\text{GE intake} = GE_{ingredient} * \text{feed consumed}$$

$$\text{GE excreted} = GE_{excreta} * \text{excreta voided}$$

A portion of the energy excreted after feed consumption which is not directly derived from the feed and is called the endogenous energy losses (EEL). EEL consists of excretory products of nitrogen metabolism, bile excretions, unabsorbed enzymes and degenerated gut linings (McNab, 1990). EEL could therefore be defined as the energy losses at zero feed intake.

Hence the energy metabolised after feed intake is only apparent. The true metabolisable energy (TME) content of a diet could then only be described when the magnitude of the EEL is known. Thus:

$$TME = \frac{\text{GE intake, MJ - GE excreted, MJ + EEL, MJ}}{\text{Feed intake, kg}} \qquad [2]$$

By substituting [1] into [2], it should be evident that [2] can also be written as :

$$TME = AME + \frac{EEL}{\text{Feed intake}} \qquad [3]$$

The assumption is made in all assays for ME determinations, that energy voided as excreta (y), is linearly related to the congruent energy intake (x). A positive intercept (a) of the fitted regression, $y = a + bx$, gives an estimate of the EEL of the experimental birds. Thus

$$\text{GE excreted} = EEL + b(\text{GE intake}) \qquad [4]$$

The complement of the slope of the line, (1-b), is an estimate of the true proportion of GE intake that is metabolisable. Thus the TME of the ingredient can then be computed as

$$TME = (1-b) * GE_{ingredient} \quad [5]$$

Theoretically, AME can similarly be calculated from the linear model in [3], by combining the given energy balance with the origin.

For the majority of ingredients the linearity of the energy balance [3], is valid and the relationship between AME and TME can be defined as in [3] (Jonsson and McNab, 1983). This model implies that variations in feed consumptions will influence the EEL per unit feed intake ratio, resulting in variation in AME estimates. However, provided that information is available on energy balance [4], feed consumption and EEL, results can be expressed either in terms of AME or TME (McNab, 1990).

The determination of AME or TME relates to a complete diet and individual values for various ingredients in a diet, should be derived from a comparison between appropriate diets. Since most single ingredients cannot be used as a complete diet under long continuous feeding conditions, it should be substituted for a known proportion of an acceptable diet (so-called basal diet). This will ensure satisfactory levels of intake and prevent digestive disorders.

By determining the ME-values of both the basal and the test diets (diets in which a proportion of the basal diet was replaced by the test ingredient), it is possible to compute the ME content of the test ingredient. This principle is called the replacement method {RM} (Hill **et al.,** 1960) and is based on the assumption that ME values are additive.

The calculation of the ME content of the test ingredient in a test diet therefore involves the following model:

$$E_t = \frac{\{E_d - E_b (1-p)\}}{p} \quad [6]$$

Where E_t = energy content of the test ingredient

E_d = energy content of the test diet (test ingredient in the basal diet)

E_b = energy content of the basal diet

p = dietary level of the test ingredient in the test diet

The digestibility of the test ingredient can similarly be calculated by replacing E_d and E_b in [6] by the appropriate digestibilities of the test diet and the basal diet.

The error (σ_{Et}) in estimating the ME or digestible coefficients for the test ingredient in [6] can be estimated by the following:

$$\sigma^2(E_t) = \{1/p^2\}\ \sigma^2(E_d) + \{(1-p)^2/p^2\}\ \sigma^2(E_b) \quad [7]$$

where $\sigma(E_t) = [\sigma^2(E_t)]^{0.5}$

By using two or more levels of substitution for the test ingredient in the basal diet and allowing two or more levels of feeding, an extended range of test ingredient and basal diet intakes is obtained. As the excreta of birds consuming the test diet, consist of undigested and unabsorbed excretions from the test ingredient and the basal diet, a multiple regression procedure is required to combine the energy balance as explained in [4].

Equation [8] represents this energy balance:

$$y = a + b_1x_1 + b_2x_2 + \varepsilon \quad [8]$$

Where y = Total GE excreted

x_1 = GE intake from basal diet (GE_{basal} * proportion of diet as basal * total feed intake)

x_2 = GE intake from test ingredient ($GE_{test\ diet}$ * total feed intake - x_1)

a = EEL

b_1 = proportion of GE from the basal diet that appears in the excreta

b_2 = proportion of the GE from the test ingredient that appears in the excreta.

ε = stochastic component or error

As explained in [5], the respective metabolisabilities, ME/GE, are $(1-b_1)$ and $(1-b_2)$. Hence TME estimates for the basal diet and the test ingredient is calculated as:

$TME_{basal\ diet} = GE_{basal\ diet} * (1-b_1)$ where [9]

$GE_{basal\ diet}$ = GE from basal diet per unit of feed

and;

$TME_{test\ ingredient} = GE_{test\ ingredient} * (1-b_2)$ where [10]

$GE_{test\ ingredient}$ = GE from test ingredient per unit of feed

Equation [9] and [10] can be combined and written as

$$ME_{total} = GE_{basal\ diet} * (1-b_1) + GE_{test\ ingredient} * (1-b_2) \quad [11]$$

where

ME_{total} = total metabolisable energy content of the basal diet and the test ingredient and $GE_{basal\ diet}$ and $GE_{test\ ingredient}$ are constants.

For the calculation of the energy balance in [8], results of several birds, were individually observed over a number of days. The stochastic or error term has two components. First there is variation between days in GE excretion (y-values in [8]) of the same bird. This variation is characterised by a variance σ^2_D. Then there is variation between birds, characterised by σ^2_B.

The value of σ^2_D can be estimated by one-way ANOVA, using the individual birds as a factor, but σ^2_B cannot be determined directly.

In estimating the coefficients b_1 and b_2 in [8], one should be aware of the components of the error term in a regression analysis. The ultimate precision of estimation is determined by the number of birds, as well as the number of observations per bird. A simple procedure for taking account of the random effects due to birds, is to perform the regression analysis using the averages (over days) of the x_1, x_2 and y values of the individual birds. The calculation of the averages yields x_{1j}, x_{2j} and y_j (j = 1, k, where k = the number of birds in the trial) which can be inserted in an ordinary multiple regression analysis, using x_{1j} and x_{2j} as the independent variables and y as the dependent or response variable.

When all these means are calculated on the same number of days (m), the "Error Mean Square" in the regression analysis is an estimate of $\sigma^2_B + \sigma^2_D/m$. However, when numbers of days vary, then the "Error Mean Square" estimates $\sigma^2_B + \sigma^2_D/m$ where

$1/m = (1/m_1 + 1/m_2 + \ldots + 1/m_k)/ k$

where m_i = the number of days for the i-th bird and k = the number of birds. Alternatively, m is the harmonic mean of the number of days per bird. When m is known and a separate estimate of σ^2_D is available, an estimate of σ^2_B can be calculated (Snedecor and Cochran, 1980)

To evaluate the error of conducting biological studies with ostriches and using the data as explained in [8], [9] and [10], the SE of ME_{total} (σ) in [11] should be considered. The variance of ME_{total} is calculated by:

$$\sigma^2(ME_{total}) = GE^2_{basal\ diet}\sigma^2(b_1) + GE^2_{test\ ingredient}\sigma^2(b_2) + 2GE_{basal\ diet}GE_{test\ ingredient}cov(b_1,b_2) \quad [12]$$

where $\sigma(ME_{total}) = [var(ME_{total})]^{0.5}$.

cov = covariance

Most statistical computer programs provide estimates for $var(b_1)$, $var(b_2)$ and $cov(b_1,b_2)$. For given $GE_{basal\ diet}$, $GE_{test\ ingredient}$ and using the estimated $\sigma^2(b_1)$, $\sigma^2(b_2)$ and $cov(b_1,b_2)$, $\sigma^2(ME_{total})$ can be estimated.

From [9] and [10], the standard errors (σ) for these TME estimates are measured as:

$$\sigma^2_{test\ ingredient} = (GE_{test\ ingredient})^2 * \sigma^2_{b2} \quad [13]$$

$$\sigma^2_{basal\ diet} = (GE_{basal\ diet})^2 * \sigma^2_{b1} \quad [14]$$

The estimated $\sigma(ME_{total})$ can be used in future experimental designs. Allowing a 5 % error (0,5 MJ ME/kg diet) in ME determinations, the number of experimental birds required to determine values within 95 % confidence limits can be calculated by [15] (Snedecor and Cochran, 1980):

$$n = 4\sigma^2 / L^2 \quad [15]$$

Where n = number of birds required

σ^2 = variance (ME_{total}) in [12]

L = allowable error

As the test ingredient was exchanged for a known amounts of basal diet, individual dry matter digestibility coefficients can also be estimated according to [8]. Similar to [9] and [10], $(1-b_1)$ and $(1-b_2)$ give estimates of the individual digestibility coefficients for the basal diet and the test ingredient respectively. The same principles regarding error of estimations in [11], [12], [13] and [14], are applicable.

A part of the feed energy that is consumed, is retained and stored as protein in the carcass and thus gives rise to an overestimation of the ME content of an ingredient. The complete catabolism of these stored protein leads to the excretion of uric acid that contains energy. For each gram of nitrogen excreted as uric acid, 36.5 kJ of energy are lost from the body (Hill **et al**., 1960). Hence it is clear that ME determinations with birds that excreted nitrogen, will cause an underestimation of the ME content of the test ingredient.

To eliminate variations in ME values as a result of varying nitrogen retention in the body, ME values should be corrected to nitrogen equilibrium. This is when nitrogen retention is zero. The nitrogen retention correction factor (NRCF) can be calculted by [16], (Wolynetz et al., 1984)

$$NRCF = \frac{\{36.5\ kJ * (N_{intake} - N_{excreted})\}}{\text{Feed intake}} \quad [16]$$

Subsequently AME_n and TME_n is calculated as follows:

$$TME_n = TME - NRCF \quad [17]$$
$$AME_n = AME - NRCF$$

The standard error of NRCF is estimated by [18]:

$$\sigma^2(NRCF) = \frac{(36.5)^2\ \sigma^2(\text{N-retention})}{(\text{Feed intake})^2} \quad [18]$$

By applying a NRCF to AME or TME values, the standard errors of these estimates will be altered and the variance of TME_n or AME_n can be estimated, by using [19]:

$$\sigma^2(TME_n) = \sigma^2(TME) + \sigma^2(NRCF) \quad [19]$$

The magnitude of nitrogen retention (RN) varies between ingredients (McNab,1990) and a regression model, similar to [8] can be applied to estimate the individual RN of birds consuming the test ingredient and basal diet respectively.

The model is:

$$y = a + b_1x_1 + b_2x_2 + \varepsilon \quad [20]$$

where y = Totale N excretion in faeces and urine

x_1 = N intake from basal diet ($N_{content\ in\ basal\ diet}$ * feed intake * proportion of diet as basal)

x_2 = N intake from test ingredient {($N_{content\ in\ test\ ingredient}$ * Feed intake) - x_1}

a = endogenous N excretion

b_1 = proportion of the N from the basal diet that was excreted

b_2 = proportion of N from the test ingredient that was excreted

ε = error

RN from the basal diet and the test ingredient is then computed by [21] and [22]:

$$RN_{basal\ diet} = (1-b_1) * N_{content\ of\ basal\ diet},\ g\ N/kg\ feed \quad [21]$$

$$RN_{test\ ingredient} = (1-b_2) * N_{content\ of\ test\ ingredient},\ g\ N/kg\ feed \quad [22]$$

NRCF for the basal and the test ingredient is the calculated according to [23] and [24]:

$$NRCF_{basal\ diet} = RN_{basal\ diet},\ g\ N/kg\ diet * 36.5\ kJ \quad [23]$$

$$NRCF_{test\ ingredient} = RN_{test\ ingredient},\ g\ N/kg\ diet * 36.5\ kJ \quad [24]$$

These estimates are then used according to [17] and [19] to derive values and errors for TME_n.

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CHAPTER 3

TRUE AND APPARENT METABOLISABLE ENERGY VALUES OF LUCERNE AND YELLOW MAIZE IN ADULT ROOSTERS AND MATURE OSTRICHES (STRUTHIO CAMELUS)

BY

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ABSTRACT

This paper deals with a comparative study of mature ostriches and poultry with respect to AME, AME_n, TME and TME_n estimations for lucerne and yellow maize. For ostriches, lucerne was used as a complete diet (basal diet) and was proportionally diluted by 50 % and 75 % of maize to compile test diet 1 and test diet 2. For poultry, maize was used as the complete diet (basal diet) and was proportionately replaced by 50 % and 25 % of lucerne to comprise test diet 1 and test diet 2. ME estimations were determined according to the replacement method (RM) and a multiple regression method (MRM). AME values of maize for ostriches amounted to 15.1 and 14.8 MJ/kg at the 50 % and 75 % levels of substitution. Similar value of 14.6 MJ/kg was observed for poultry. AME_n values of maize in ostriches amounted to 14.3 and 14.5 MJ/kg, while a estimate of 14.5 MJ/kg was derived for poultry. AME values of lucerne in roosters amounted to 4.44 and 5.06 MJ/kg at the 50 % and 25 % levels of substitution, while a substantially improved value of 9.3 MJ/kg was determined for ostriches. AME_n values were 4.05 and 4.49 MJ/kg for roosters as opposed to 8.9 MJ/kg for ostriches.

In the MRM, no intercept was computed, hence no estimation of endogenous energy losses (EEL) could be established. These findings support Härtel's (1986) observation of the absence of EEL under continuous feeding, and that TME = AME under these conditions. TME estimates of lucerne for ostriches and roosters were 9.2 and 4.26 MJ/kg, respectively, while TME for maize as estimated as 14.9 and 14.76 MJ/kg. Substantially improved TME_n values of 8.6 MJ/kg vs. 4.03 MJ/kg were derived for ostriches and poultry, while estimates of 14.9 and 14.65 MJ/kg were calculated for maize. The importance of the evaluation of feedstuffs for ostriches and not to simply rely on values established with poultry, is stressed by the present study where markedly improved ME values, independent of the calculation (AME, AME_n, TME and TME_n) were observed for lucerne in ostriches, while only small differences were observed for maize between the two species.

INTRODUCTION

There is a growing interest world-wide in ostrich farming and although it is a well established industry in South Africa, very little published information is available on the nutritional values of feedstuffs normally used for making ostrich diets. Nutrient values for swine or poultry are thus employed in diet formulation.

However, metabolisable energy (ME) is actually a characteristic of the animal to which it is given. Therefore it is crucial to know to what extent this assumption is valid for the economic formulation of diets for ostriches under intensive rearing conditions.

Swart (1986) demonstrated the production of volatile fatty acids, in particular acetate, in the colon of immature growing ostriches. Digestibility coefficients of 0.66 for hemicellulose and 0.38 for cellulose in a diet containing 340 g/kg lucerne meal were found. He concluded that the end products of fibre fermentation could contribute as much as 0.76 of the ME requirements for maintenance of the growing ostrich. The use of ME values for poultry and swine, in diet formulation for ostriches, will thus result in an underestimation of the ME content of an ingredient.

The present study was therefore an attempt to establish ME values, corrected to zero nitrogen retention

(AME_n and TME_n) of maize and lucerne for mature ostriches and to compare such values simultaneously with those found in roosters.

MATERIAL AND METHODS

Diets

OSTRICHES

It was not clear whether ostriches could be fed on maize as a complete diet for a continuous period without causing digestive disorders. Hence lucerne was used as a complete diet (basal diet). Three combinations were used viz.:

Treatment 1 received lucerne meal as a basal diet (100 %)

Treatment 2 received 50 % lucerne and 50 % maize (test diet 1)

Treatment 3 received 75 % lucerne and 25 % maize (test diet 2)

All diets were pelleted to prevent separation of components and to limit feed wastage.

POULTRY

The same samples of lucerne hay and maize were used to compile three diets for roosters:

Treatment 2 received 75 % maize and 25 % lucerne (test diet 1)

Treatment 3 received 50 % maize and 50 % lucerne (test diet 2)

Treatment 4 received maize as a basal diet (100 %)

These diets were identical to test diets offered to ostriches. Hence for comparison purposes, test diet 1, test diet 2 and the poultry basal diet, represented Trt 2, Trt 3 and Trt 4. respectively (Table 2).

Animal husbandry and protocol

OSTRICHES

Swart (1986) described a procedure of collecting excreta from young ostriches in ordinary plastic bags with adhesive plaster. This method failed in more mature birds due to substantially increased quantities of voidings, hence denim harnesses were designed to allow free movement in metabolism crates. An adjustable stomach girdle was linked to the harness which was used to hold a canvas bag. The canvas bag consisted of a plastic lining which fitted snugly over the entire tail region of the bird, thus enabled the quantitative collection of excreta during the collection period. Photo 1 to photo 13 clearly illustrated the design of the excreta collection harness and its utilisation in collecting excreta.

The three treatments were allocated at random to 15 mature ostrich males that weighed between 100 and 120 kg. A preliminary feeding period of 7 days was allowed in which the experimental diets were offered. The aim of this adaption period was to establish an equilibrium in the flow of the contents in the digestive tract before the assay period commenced. This was followed by an 5 day experimental period in which feed intake and excreta production were accurately measured.

During the assay period, birds were placed in wooden metabolic crates to which they were already accustomed. All tail feathers were removed to prevent contamination of excreta. Preliminary trials were conducted to allow the birds to adjust to the crates, the harnesses and the emptying of the collection bags on the harnesses. Feed and water were available at all times and daily consumptions were measured at the same time as excreta collections were done. Spilled food could be quantitatively collected on trays below the crate floors. The bags were emptied four times per day to prevent losses during squatting.

POULTRY

The three experimental diets were offered at random to thirty individually caged adult Australop cockerels,

with an average weight of 3 kg. The dual semi-quick (DSQ) method (Du Preez, Duckitt and Paulse, 1986) was applied in which birds were starved for 20 hours, then accustomed to the diets for one day, followed by a total collection of excreta for three days, while feed was available at all times.

Handling of samples and analysis

The daily voidings were kept separate and stored at -10°C until further processing. Excreta and samples of experimental diets were dried in a forced draft oven at 80 °C until attainment of a constant weight, after which equilibration with atmospheric moisture was allowed for 24 h. The gross energy (GE) of the finely ground excreta and feed were determined in a solid state bomb calorimeter (Digital Data System CP 500) for daily excretions of the ostriches. Nitrogen (N) was measured by the standard macro-Kjeldahl procedure. Dry excreta of daily voidings of individual ostriches were then proportionally pooled over days and used for N-analysis. For poultry however, excreta samples collected over the total collection period were analised for GE and nitrogen.

RESULTS

A. Ostriches

1. *ME calculation by the Replacement Method (RM)*

Average daily intakes (kg) were 1.86 and 2.01 for Trt 1 and Trt 2, but lower intakes of 1.58 {$p < 0.05$} were observed for Trt 3 (Table 1). This was probably the result of the higher energy content of this diet.

As could be expected, dry matter digestibility (DMD) was improved from 0.49 to 0.73 as dietary levels of maize increased from 0 % to 75 % in the experimental diets (Table 1). DMD for maize amounted to 0.83 and 0.81 in Trt 2 (50 % substitution) and Trt 3 (75 % substitution), while the DMD of lucerne (Trt 1) was estimated as 0.49 {Table 4}.

No significant day to day variation was observed in AME values for individual birds on the same diet or between birds receiving the same diet. AME values (MJ/kg) of 9.3, 12.2 and 13.4 were measured for birds on Trt 1, Trt 2 and Trt 3, respectively (Table 1). With an AME of 9.3 MJ/kg for lucerne, the calculated AME value for maize amounted to 15.1 and 14.8 MJ/kg in Trt 2 and Trt 3 (Table 4), respectively.

By applying a N-retention correction factor (NRCF), substantially reduced AME_n values (MJ/kg) of 8.9 and 11.6 were observed for the basal diet and test diet 1. However for the lower protein diet in Trt 3, AME_n remained fairly constant at 13.1 MJ/kg (Table 1). AME_n values for maize was estimated accordingly and amounted to 14.3 and 14.5 MJ/kg in Trt 2 and Trt 3 (Table 4). Hence the overall effect of correcting for N-retentions was a reduction in the differences between ME values for maize at the various levels of substitution. This phenomenon was probably caused by differences in the rate of feeding (Table 4).

2. *ME calculation by using the Multiple Regression Method (MRM)*

DMD coefficients calculated by a multiple regression method over all treatments, yielded estimates of 0.88 and 0.53 for maize and lucerne respectively (Table 5).

Using daily measurements of feed intake and fecal excretions for the calculation of the unmetabolisable energy proportions in lucerne and maize, resulted in estimates of 0.42 (± 0.0370) and 0.1 (± 0.0430), respectively (Table 3). The error term in these estimations consists of day to day variation between the same bird ($\sigma^2_{D)}$ and variation between birds (σ^2_{B}). σ^2_{D} was calculated as 4.96 and the indirect calculation of σ^2_{B}, showed that $\sigma^2_{B} = 0$. This finding suggests that if the individual data of day to day measurements are used, irrespective of bird, the estimates for b_1 and b_2, with standard errors, should be comparable to those calculated on the means of treatments.

The accuracy of these findings were evaluated by comparing these results to the unmetabolisable proportions, b_1 and b_2, computed on means over days. Similar estimates of 0.47 (± 0.0340) and 0.15 (± 0.0400) were observed for lucerne and maize respectively, but significant improvements in standard errors and coefficient of determination (R^2) were computed (Table 3). Hence, averaging measurements for individual birds over the total collection period and using these data in balance studies, seemed more appropriate.

No significant intercept ($p > 0.05$) was found in neither of the regressions relating excreted energy to energy intake (Table 3) and the estimation regarding endogenous excreta could not be established so that AME = TME. Using the metabolisable fractions ($1-b_1$) and ($1-b_2$) in this energy balance, the TME values for lucerne and maize were estimated as 9.2 and 14.9 MJ/kg.

The standard error for ME determinations with lucerne and maize amounted to 1.20. Using this value and allowing a margin of error of 0.5 MJ/kg, the number of birds required for ME determinations with 95 % confidence limits, was calculated as 12 birds.

Using multiple regression to assess N retention for birds on lucerne and maize, indicated that birds on maize were in N-equilibrium (Table 3). Lucerne however promoted the retention of protein and a positive N-retention of 16.7 g N/ kg lucerne was observed (Table 5). By using this estimate the TME_n of lucerne was reduced to 8.6 MJ/kg.

B. Poultry

1. *ME calculation by the Replacement Method (RM)*

Feed intake of roosters decreased as lucerne levels increased in diets, but similar consumptions were observed between birds receiving the same diets. Average daily intakes of 87, 77 and 68 g were measured for birds receiving the basal diet (Trt 4), test diet 2 (Trt 3) and test diet 1 (Trt 2), respectively (Table 2).

DMD between birds revealed little variation (CV = 1.68 %). Digestibility increased linearly from 0.473 to 0.828 as dietary levels of lucerne was reduced from 50 % to zero (Table 2). With a DMD value of 0.828 for maize, the DMD for lucerne was calculated and amounted to 0.118 and 0.072 for Trt 2 and Trt 3 (Table 4).

A linear increase in AME values were observed as dietary levels of maize were increased and values of 9.53, 12.03 and 14.62 MJ/kg were determined for Trt 2, Trt 3 and Trt 4 (Table 2). The AME value for maize of 14.62 MJ/kg was used to estimate AME values for lucerne and these amounted to 4.44 (± 0.530) and 4.05 MJ/kg at the 50 % and 25 % levels respectively (Table 4).

Significant lower estimates of N-retentions, 0.32 g/day (± 0.0938) were found for birds receiving the complete maize diet (Trt 4) as compared to birds consuming Trt 2 (0.48) and Trt 3 (0.51) . Applying NRCF, reduced AME_n values (MJ/kg) to 9.27, 11.99 and 14.49 for Trt 2, Trt 3 and Trt 4, respectively (Table 2). The AME_n estimates for lucerne at dietary levels of 50 % and 25 % replacement, were calculated accordingly and amounted to 4.05 and 4.49 MJ/kg, respectively. The application of the NRCF reduced differences between the ME estimates for lucerne at the two levels of substitution which was probably the result of differences in the levels of lucerne intakes.

2. *ME calculations by using the Multiple Regression Method (MRM)*

Calculation of DMD according to MRM, yielded values of 0.108 and 0.823 for lucerne and maize respectively (Table 3 and Table 5).

The regression line relating energy excretion to energy consumption passed through the origin and no estimate for endogenous energy losses could be calculated. TME values of 4.26 and 14.76 MJ/kg were determined for lucerne and maize respectively (Table 5).

The standard error in estimating the TME values for lucerne and maize amounted to 0.442. Thus for the allowance of a 5 % error (0.5 MJ/kg) in future ME determinations, only 4 birds will be required to estimate values within 95 % confidence intervals.

The multiple regression relating the N-balance between consumption from lucerne and maize to total excretion, showed a positive intercept of 0.34 which estimated endogenous N excretions (Table 3).

Birds on lucerne and maize were in positive N-balance and excretions of 6.22 and 3.1 g N/kg ingredient were estimated (Table 5). By using the energy equivalents for these excretions, TME values were corrected to RN = 0 and this yielded estimates of 4.03 and 14.65 MJ/kg for lucerne and maize respectively (Table 5).

DISCUSSION

Various methods are used in ME determinations of feedstuffs for poultry and references are based on factors such as speed, cost and convenience of the experimental procedure (Fisher and McNab, 1987). For ostriches however, no information was available on such procedures and the only consideration in the present study was to obtain reliable results which could serve as a basis for future work. It was therefore decided that the conventional balanced method, often used in poultry, would be the most suitable method as an initial test to apply to ostriches.

A 7 day adaption period in the experimental diets before feed intake and excreta collection commences can probably be regarded as more than adequate especially in the light of work done by Swart (1986). He reported feed transit times in ostriches varied between 21 and 76 hours within groups of similar weights, with an average estimate of 40.1 hours.

Identical estimates for DMD (0.83) for maize were observed in poultry and ostriches using the RM of calculation. A slightly higher value of 0.88 was seen for ostriches if the MRM was used. The significant improved estimates for DMD in lucerne (0.53) for ostriches in comparison to 0.11 for poultry (Table 4), confirmed the findings by Swart (1986) of the ability of ostriches to digest plant fibres such as cellulose and hemicellulose.

Enhanced DMD for lucerne also explains the significantly higher metabolisability of lucerne viz. 9.2 MJ/kg for ostriches, as compared to 4.26 MJ/kg for poultry (Table 5). Sibbald (1981), reported zero values for the metabolisability of cellulose, probably due to short retention times that caused the inability of poultry to digest plant fibre to any significant extent.

The substantial difference in AME estimates of lucerne for poultry at the two levels of substitution was probably the result of the level of lucerne intake and the effect of EEL at these lower levels (Table 4). Differences between AME estimates for maize at the two levels of feeding in ostriches, were not markedly different, probably as higher levels of maize intake was observed as a result of higher levels of substitution. It is well realised that at low levels of intake, EEL makes a disproportionate contribution to the excreta and therefore depressing AME and AME_n values.

Results in the present study is in support to the findings of Härtel (1986) and Johnson (1987) viz. that endogenous energy is a characteristic of the method of feeding. These workers concluded that correction for endogenous energy is only necessary when precision feeding is practised, i.e. when placing a known amount of feed in the crop of a bird.

Farrell **et al.** (1991) concluded that the EEL of continuously fed birds is comparatively low and this probably

explained why no EEL could be measured (estimated) in the present study (Table 3). With the variation in the estimation of EEL as outlined for poultry (Farrell **et al.**,1991), AME seems more than reliable for energy determinations with ostriches.

The correction of ME values to N-equilibrium made little difference in poultry,, but markedly reduced the AME values of lucerne for ostriches from 9.2 to 8.6 MJ/kg (Table 5). Substantially higher degree of variation was observed for ME values in ostriches as opposed to that for poultry. This can probably be explained by a between bird variation in fibre digestibility. For the estimation of ME values for ostriches within 95 % confidence limits, 12 birds were required in comparison to only 4 for poultry. These findings are in contrast to the suggestions made by Swart (1986), where only 5 animals were suggested for ostriches due to lower variation observed in ME estimations. It should however be noted that Swart (1986), fed a so-called balanced diet and used birds of 50 kg in body weight. It is possible that the latter findings can be ascribe to age differences between experimental animals and this is an aspect for further investigation .

The inconsistency and higher SE for DMD and AME estimates at the 2 levels of substitution of the test ingredients for poultry and ostriches in the RM, clearly demonstrated that the level of substitution of a test ingredient in a test diet will influence the accuracy of the estimation (Table 4). The higher the level of substitution, the more accurate will the estimate be.

Comparing estimates for DMD, TME and TME_n as determined by the MRM to that of the RM (Table 4 and Table 5), showed that MRM consistently yielded values with lower SE for both ostriches and poultry. Hence it is clear that the MRM is a more reliable procedure for the estimation of the nutritional characteristics of ingredients.

The importance of the evaluation of feedstuffs for ostriches and not to simply rely on values established with poultry, is stressed by the finding of a TME_n values of 8.6 MJ/kg for lucerne in mature ostriches as opposed to 4.03 MJ/kg for poultry. The efficient and economic formulation of diets for ostriches will be determined by future research.

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TABLE 1 AVERAGE VALUES OF PROTEIN CONTENT, FEED INTAKE, DRY MATTER DIGESTIBILITY, AME, RN AND AME_n VALUES OF DIETS, FED TO MATURE OSTRICHES.

ESTIMATES	TRT 1: Basal diet 100 % lucerne	TRT 2: Test diet 1 50 % lucerne; 50 % maize	TRT 3: Test diet 2 25 % lucerne; 75 % maize
Determined protein, %	15.6 ± 0.194	13.8 ± 0.128	11.3 ± 0.0957
Feed intake, kg/day	1.86 ± 0.178^{ab}	2.01 ± 0.246^{a}	1.58 ± 0.177^{b}
Dry matter digestibility	0.49 ± 0.0389^{a}	0.66 ± 0.0416^{b}	0.73 ± 0.0309^{c}
AME, MJ/kg diet	9.3 ± 0.640^{a}	12.2 ± 0.657^{b}	13.4 ± 0.479^{c}
RN, g/day	24 ± 2.71^{ab}	30 ± 4.11^{a}	16 ± 2.68^{b}
AME_n, MJ/kg diet	8.9 ± 0.725^{a}	11.6 ± 0.755^{b}	13.1 ± 0.550^{c}

Estimates within the same row with common superscripts, do not differ significantly ($p > 0.05$)

TABLE 2. AVERAGE VALUES OF PROTEIN CONTENT, FEED INTAKE, DRY MATTER DIGESTIBILITY, AME, RN AND AME_n VALUES OF DIETS, FED TO MATURE POULTRY

ESTIMATES	TRT 2: Test diet 1 50 % lucerne; 50 % maize	TRT 3: Test diet 2 25 % lucerne; 75 % maize	TRT 4: Basal diet 100 % maize
Determined protein, %	13.8 ± 0.202	11.3 ± 0.151	8.71 ± 0.204
Feed intake, g/day	68 ± 5.90^{ac}	77 ± 6.16^{bc}	87 ± 3.10^{b}
Dry matter digestibility, %	47.3 ± 0.525^{a}	63.9 ± 0.514^{b}	82.8 ± 0.258^{c}
AME, MJ/kg diet	9.53 ± 0.096^{a}	12.23 ± 0.0847^{b}	14.62 ± 0.0374^{c}
RN, g/day	0.48 ± 0.113^{ab}	0.51 ± 0.0646^{a}	0.32 ± 0.0242^{b}
AME_n, MJ/kg diet	9.28 ± 0.156^{a}	11.85 ± 0.115^{b}	14.2 ± 0.0462^{c}

Estimates within the same row with common superscripts, do not differ significantly ($p > 0.05$)

TABLE 3. PARAMETERS FOR DRY MATTER DIGESTIBILITY, METABOLISABILITY AND N-RETENTION, ESTIMATED BY MULTIPLE REGRESSION, $y = a + b_1x_1 + b_2x_2$, FOR LUCERNE AND MAIZE IN MATURE OSTRICHES AND POULTRY.

ESTIMATES	DM Digestibility	Energy Balance[1]	Energy Balance[2]	N-Balance
Ostriches				
Intercept	0.09 ± 0.0748*	1.2 ± 1.19*	-0.20 ± 1.08*	6 ± 3.51*
b_1 for lucerne	0.47 ± 0.0403	0.42 ± 0.0370	0.47 ± 0.0340	0.33 ± 0.0770
b_2 for maize	0.12 ± 0.0474	0.10 ± 0.0430	0.15 ± 0.0400	0.0629 ± 0.136*
R^2	0.778	0.771	0.961	0.746
Poultry				
Intercept	0.02 ± 0.015*		-0.03 ±0.0464*	0.34 ± 0.113
b_1 for maize	0.177 ± 0.0104		0.158 ± 0.0103	0.44 ± 0.0948
b_2 for lucerne	0.892 ± 0.0173		0.754 ± 0.0166	0.411 ± 0.0715
R^2	0.993		0.991	0.525

* Values not significantly different from zero ($p > 0.05$)

1 Energy balance based on day to day measurements

2 Energy balance based on means over the entire collection period

TABLE 4. THE AME, AME_n AND DM DIGESTIBILITIES OF MAIZE AND LUCERNE FOR MATURE OSTRICHES AND POULTRY, AS DETERMINED BY THE REPLACEMENT METHOD.

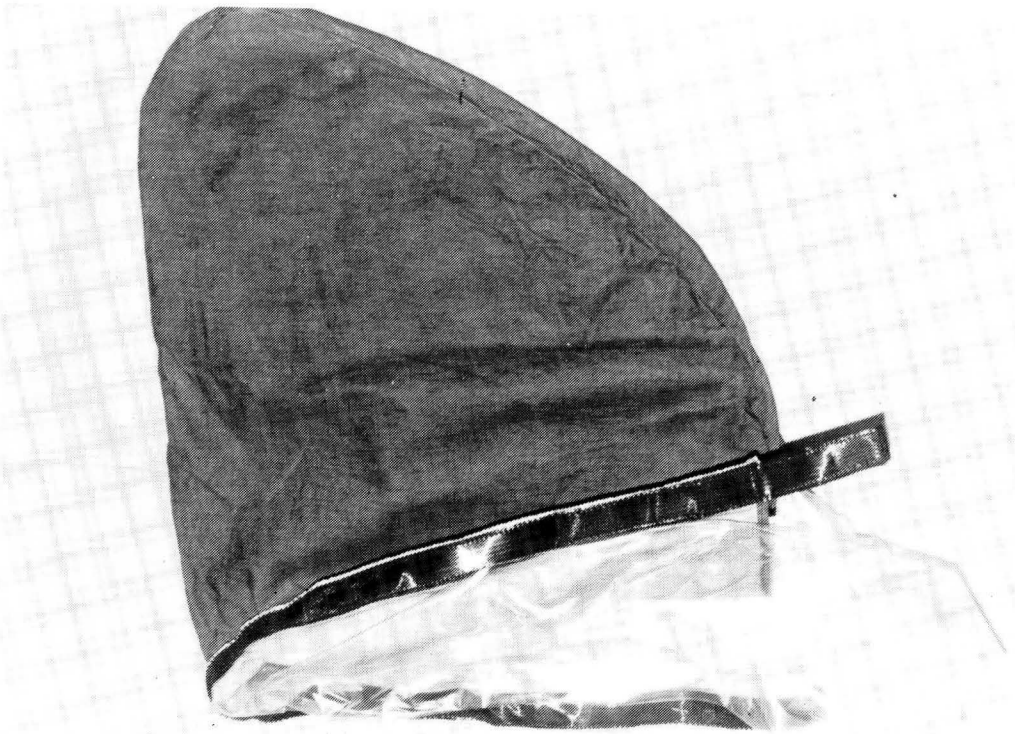
ESTIMATES	Replacement method		
	AME MJ/kg	AME_n MJ/kg	DMD
Ostriches			
Maize in TRT 2 at 50 % level	15.1 ± 1.61	14.3 ± 1.81	0.83 ± 0.103
Maize in TRT 3 at 75 % level	14.8 ± 0.75	14.5 ± 0.845	0.81 ± 0.048
Lucerne in TRT 1 at 100 % level	9.3 ± 0.715	8.9 ± 0.755	0.49 ± 0.0436
Poultry			
Lucerne in TRT 2 at 50 % level	4.44 ± 0.200	4.05 ± 0.321	0.118 ± 0.0111
Lucerne in TRT 3 at 25 % level	5.06 ± 0.376	4.49 ± 0.506	0.072 ± 0.0235
Maize in TRT 4 at 100 % level	14.62 ± 0.0374	14.49 ± 0.0460	0.828 ± 0.00258

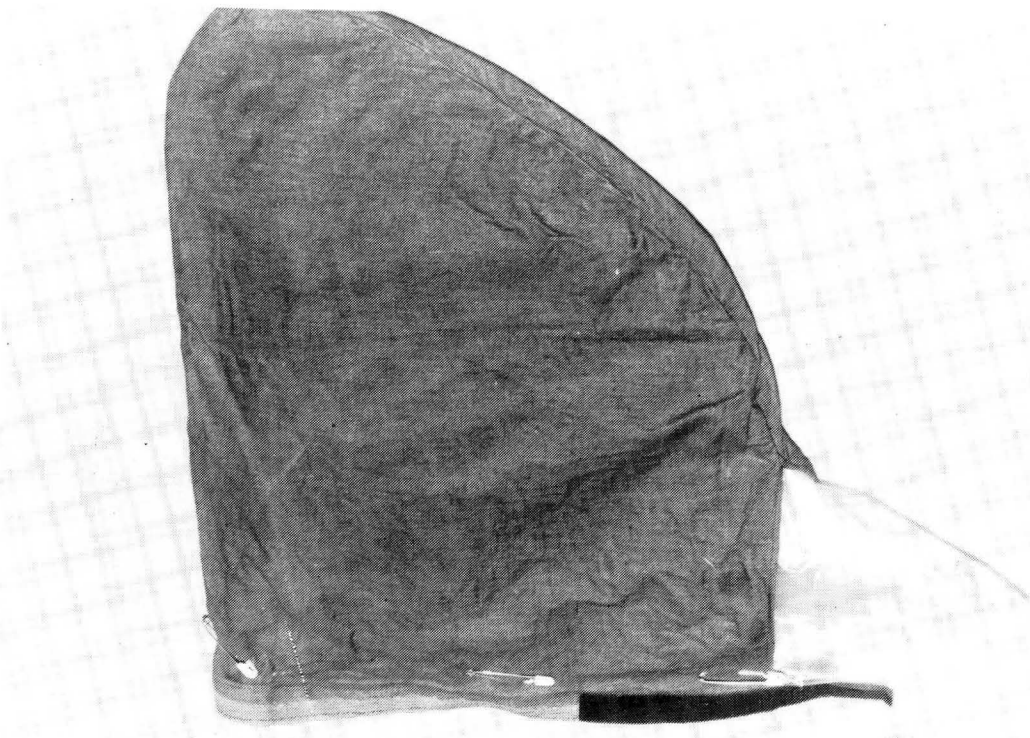
TABLE 5. THE TME, TME_n, DM DIGESTIBILITIES AND RN OF MAIZE AND LUCERNE FOR MATURE OSTRICHES AND POULTRY, AS DETERMINED BY THE MULTIPLE REGRESSION METHOD.

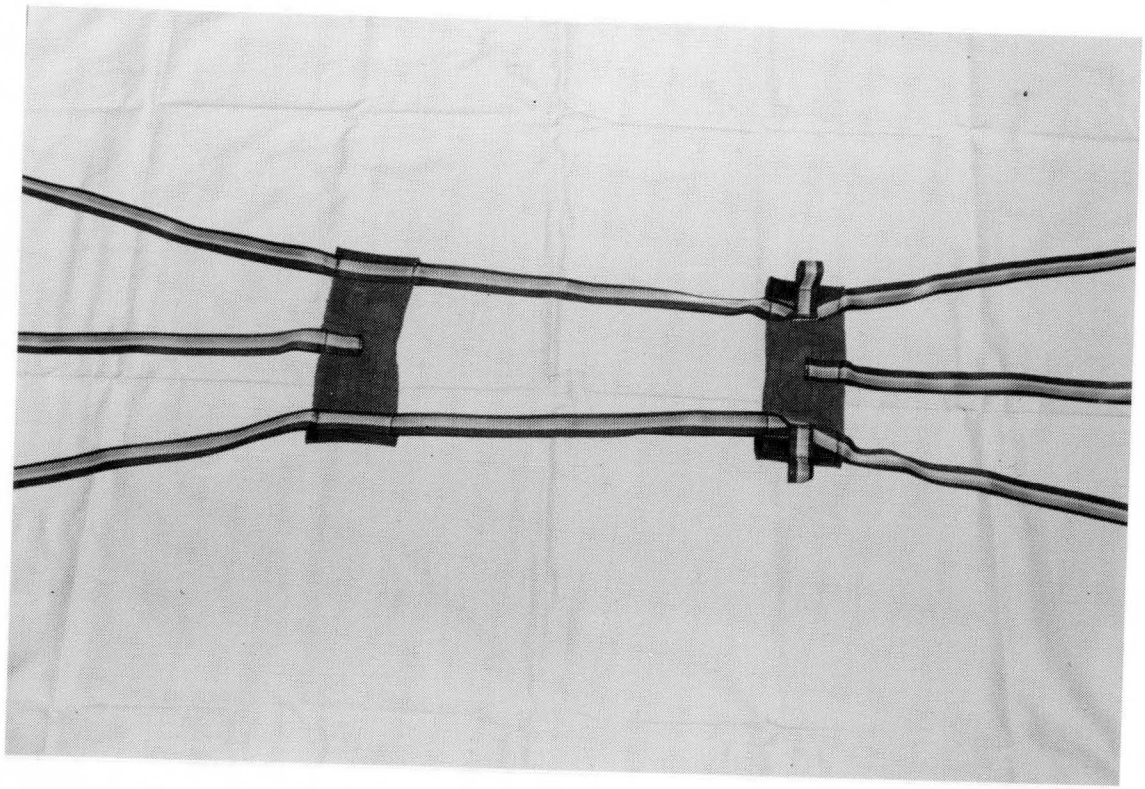
ESTIMATES	Multiple regression method			
	TME MJ/kg	TME_n MJ/kg	DMD	RN g N/kg DIET
Ostriches				
Maize	14.9 ± 0.351	14.9 ± 0.351*	0.88 ± 0.0237	0*
Lucerne	9.2 ± 0.294	8.6 ± 0.296	0.53 ± 0.0202	16.7 ± 0.96
Poultry				
Lucerne	4.26 ± 0.108	4.03 ± 0.118	0.108 ± 0.00654	6.22 ± 1.26
Maize	14.76 ± 0.0467	14.65 ± 0.0455	0.823 ± 0.00269	3.1 ± 0116

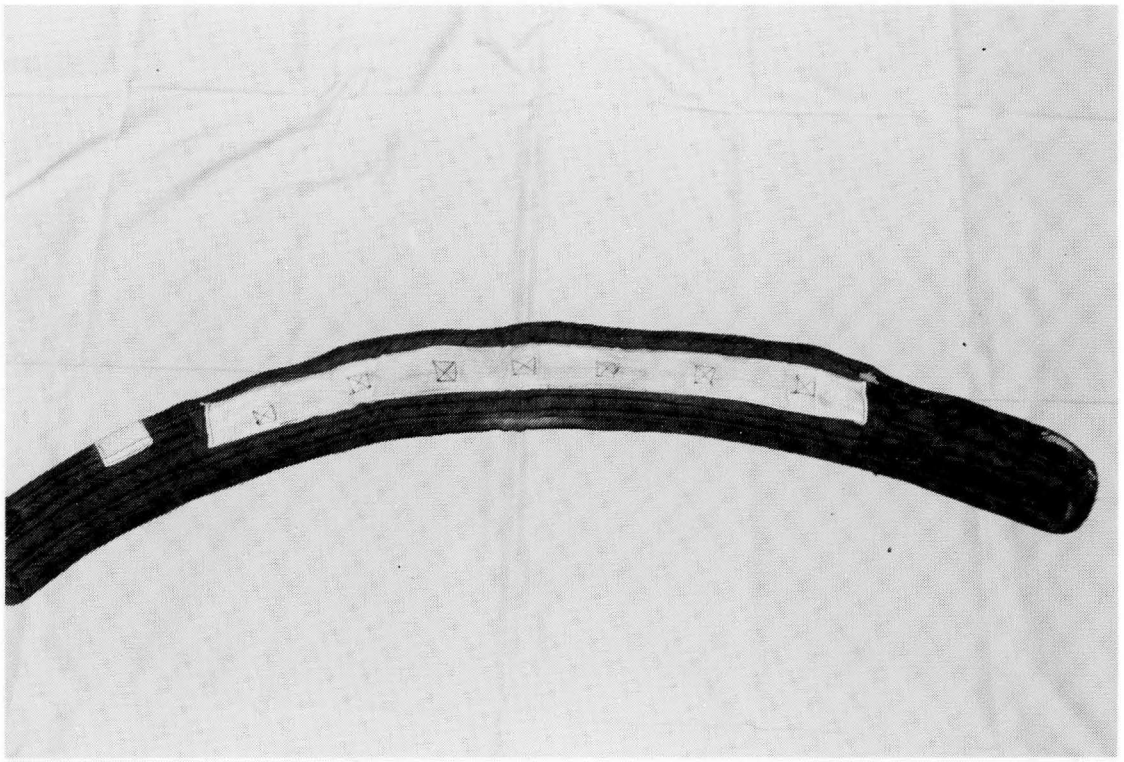
* Birds were in N-equilibrium, hence AME = AME_n.

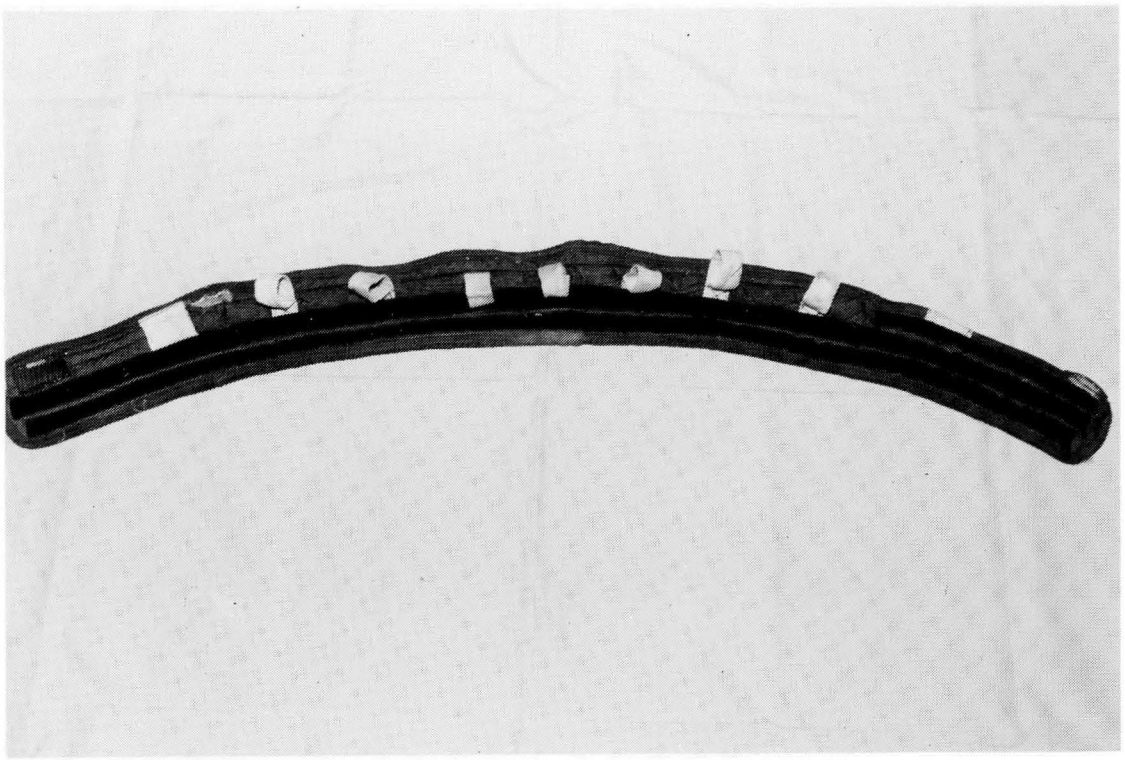
As no intercept was calculated ($p>0.05$), TME = AME

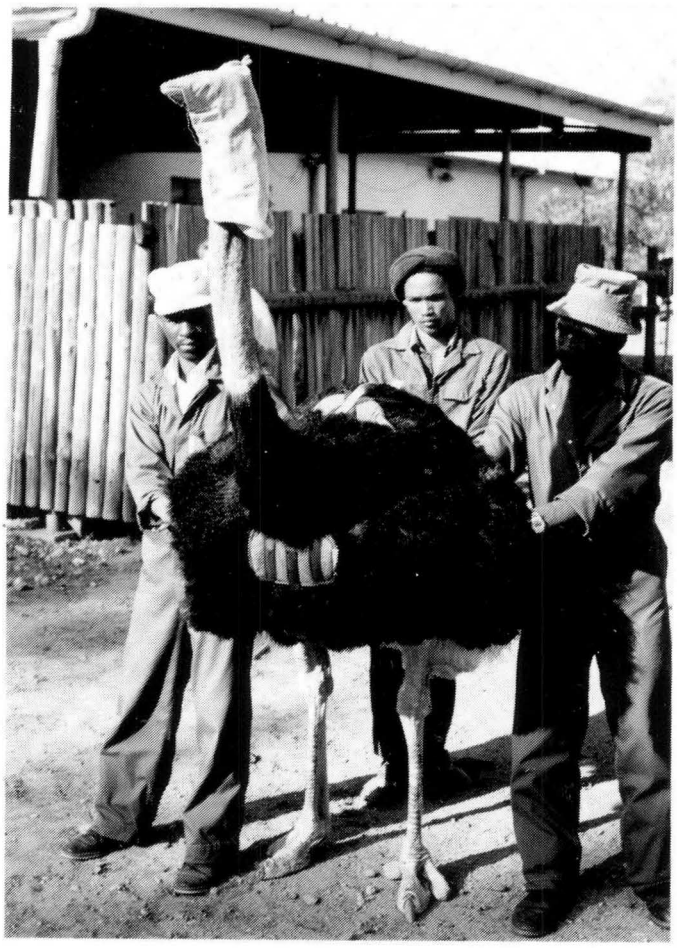


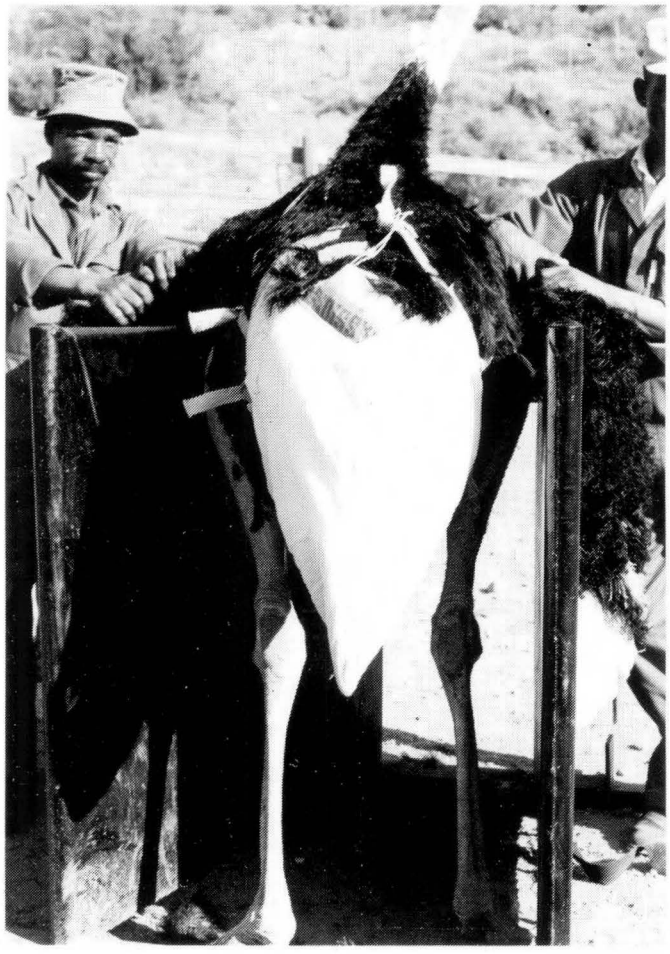


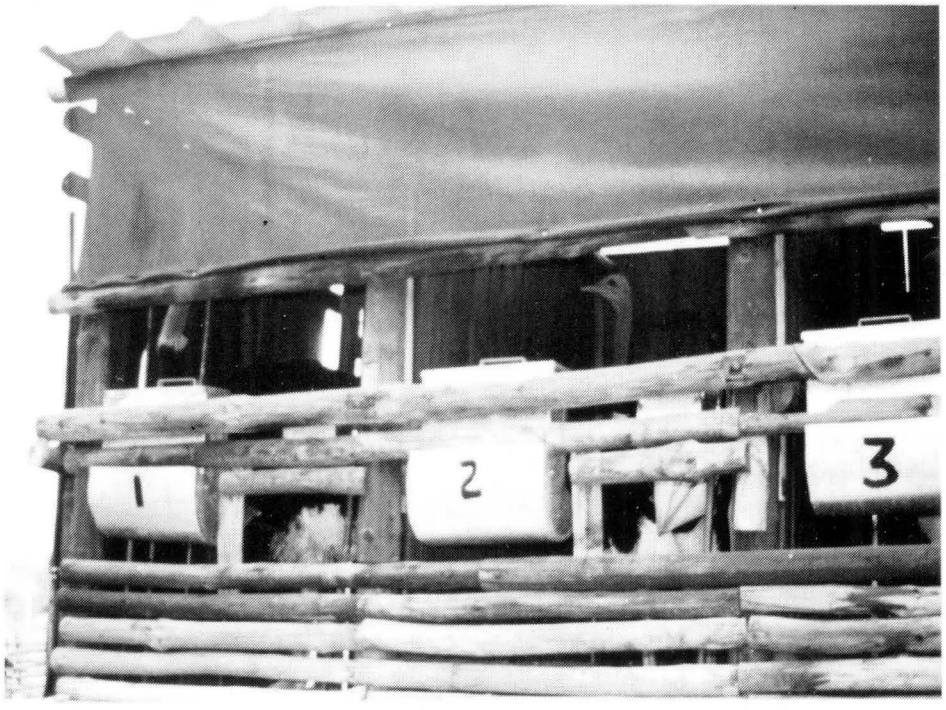












CHAPTER 4

A COMPARATIVE STUDY BETWEEN MATURE OSTRICHES (STRUTHIO CAMELUS) AND ADULT ROOSTERS WITH RESPECT TO TRUE AND APPARENT METABOLISABLE ENERGY VALUES FOR MAIZE, BARLEY, OATS AND TRITICALE

BY

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ABSTRACT

In three successive trials with roosters and mature ostrich males, the apparent and true metabolisable energy values, corrected for nitrogen retention (AME_n and TME_n) were determined by balance method for malting barley, oats, triticale and yellow maize. All these ingredients were used as sole dietary components with the exception of triticale in ostriches which was diluted with 440 g/kg lucerne meal. The balance trial with the ostriches lasted for 5 days after an adaption period of 7 days and 72 hours for roosters after an adaption period of 24 hours.

AME_n values for roosters of malting barley, oats, triticale and maize amounted to 11.06, 10.48, 11.44 and 14.42 MJ/kg respectively. Significantly improved values of 14.21, 12.65, 12.60 and 14.89 MJ/kg were determined for malting barley, oats, triticale and maize in ostriches.

TME_n values determined by regression method, yielded similar values in ostriches of 13.92, 12.27, 13.21 and 15.22 MJ/kg for malting barley, oats, triticale and maize respectively. The corresponding TME_n values in roosters were 11.33, 10.63, 11.82 and 14.07 MJ/kg.

The capability of ostriches to utilise the fibre in energy sources more efficiently, confirmed previous findings by Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994) of enhanced digestibilities for high fibre ingredients as apposed to that of poultry. The improved energy values observed for the various energy sources also indicated that the non-starch polysaccharide like ß-glucans and arabinoxylans in

the more fibrous energy sources had little nor any effect on the available energy of these ingredients as encountered in poultry. The potential of ostriches to utilise the more fibrous energy sources like barley, oats and triticale open the economical use of various energy sources in diet formulation. This possibility may result in markedly reduced feed costs for ostriches.

INTRODUCTION

Maize, traditionally over the years became the primary dietary energy source in commercial monogatric diets as it proved to be the highest concentrated energy feedstuff for the industry. Grains such as barley, oats and triticale contain inferior levels of bioavailable energy that limited its use in diets.

The lower energy content of these ingredients in poultry is caused by higher fibre contents and more important, the presence of anti-nutritional factors namely arabinoxylan and ß-glucan (Burnett, 1966; Aman & Hesselman, 1984; Choct & Annison, 1990; Annison, 1993). These non-starch polysaccharide cell wall components increases the vicosity of the intestinal contents and inhibit protein, lipid and starch digestion and assimilation.

In a recent study by Cilliers, Hayes, Maritz, Chwalibog and Du Preez (in for publication), the findings of Swart (1986) was confirmed that ostriches have the ability to utilise fibre and TME_n values for lucerne was 53 % higher than the values determined for poultry. These findings lead to the expectation that ostriches may have the ability to utilise the higher fibre contents of barley, oats and triticale as opposed to that of maize, resulting in higher bioavailable energy contents for these ingredients. The question however arises whether the non-starch polysaccharide cell components will have a similar adverse effect on the energy content of these ingredients as were observed for poultry ?

The present study was therefore an attempt to establish metabolisable energy values, corrected to zero nitrogen retention (TME_n and AME_n) of barley, oats, triticale and maize for mature ostriches and to compare these estimates to those found simultaneously in adult roosters.

MATERIAL AND METHODS

Diets and Treatments

Malting barley, oats (feed grade), triticale and maize were used as such to compile the test diets for the adult roosters. For the ostriches however, triticale was diluted by 440 g/kg of lucerne while oats, malting

barley and maize were used as complete diets. For the proportional estimation of the energy value of triticale from the test diet (440 g/kg lucerne and 560 g/kg triticale), a 1000 g/kg lucerne diet (basal diet) was also fed. Diets were cold pelleted (6 mm) to minimise wastage.

Animal Husbandry

The conventional balance procedure which is normally used at this institution to determine the TME_n and AME_n contents of ingredients was applied to 40 adult roosters (males of the Lohmann Brown laying strain). The birds were singlely housed with their own feed and water trough and excreta collection tray.

Roosters were fasted for 20 hours after which a feeding period of 4 days were employed. Feed was supplied *ad lib* and intake and collection of excreta were quantitively measured over the last 72 hours so that the first 24 hours served as an adaption period to the new diets. This ensured correction for end-losses in the intestinal tract (Du Preez, Duckitt & Paulse, 1986). The room was temperature and light controlled.

Fully grown-out mature ostrich males (120 kg), trained and regularly used in feeding experiments were housed in wooden metabolism crates each having its own water and feed supply. Wasted feed could be accurately collected on trays below the crates. Thirty six crates were available in an open sided building and 12 birds per diet were used for experimentation. Two successive trials were conducted, first with maize, barley and oats and in the second trial, the 1000 g/kg lucerne diet and the 440 g/kg lucerne and 560 g/kg triticale diet were given. Excreta were collected in canvass bags with plastic linings which is attached to the harness fitted to each bird. The harnesses were made from soft denim to allow comfort and free moving of birds in the crates. The canvass bags fitted snugly over the entire tail area that enabled the quantitative collection of excreta during the balance period. The bags were emptied four times daily to prevent losses during squatting. The ostriches were allowed to adapt to the diets for 7 days before feed intake and excreta collection was measured for a further period of 5 days. Feed and water were provided *ad lib.*. Daily excreta voidings were kept separate and stored at - 10 °C until further processing.

Analytical Procedures

Excreta were dried in an forced draft oven at 80°C to constant weight whereafter equilibration with atmospheric moisture was allowed for 24 hours. Dry excretions of daily collections for the ostriches were proportionally pooled over days and used in analysis. Gross energy (GE) of the finely ground

excreta and experimental diets were determined in a solid state bomb calorimeter (Model CP 500, Digital Data Systems, P.O. Box 35872, Northcliff, Johannesburg. Nitrogen (N) was measured according to the macro-Kjeldahl procedure.

Calculation and statistical analysis of results

Dry matter digestibility (DMD) was calculated by averaging individual measurements for the various ingredients and also by regressing excreta output (y) to feed intake (x). The slope (b) of this linear regression represents the undigestible proportion of the ingredient, hence DMD is calculated as 1 - b.

For the correction of apparent metabolisable energy values to zero nitrogen retention (AME_n), the factor of 36.5 kJ/g N retained were used. As most of the test ingredients were fed as complete diets, calculation of the AME_n values were done directly. The AME_n estimate for triticale in ostriches was indirectly calculated by the replacement method (Hill, Anderson, Renner & Carew, 1960) from the values obtained for the 1000 g/kg lucerne diet Basal diet) and the test diet (440 g/kg lucerne & 560 g/kg triticale).

For the calculation of true metabolisable energy values (TME) of barley, oats and maize, gross energy (GE) intake (x) from these ingredients was regressed on the congruent gross energy excretion (y). This included all birds and levels of intake for each individual test ingredient. The complement of the slope of this linear regression (1 - b), yielded an estimate of the true proportion of the GE intake that was metabolisable (McNab, 1990). Hence the TME of the ingredient is calculated as

$$TME = (1-b) * GE_{\text{test ingredient}}$$

For the ostriches where triticale was fed in a test diet together with lucerne, a multiple regression was applied in which GE intake from lucerne (x_1) and GE intake from triticale (x_2) were simultaneously regressed on the corresponding total GE excretion (y). The TME values of lucerne and triticale could then be calculated as:

$$TME_{\text{lucerne}} = (1-b_1) * GE_{\text{lucerne}}$$
$$TME_{\text{triticale}} = (1-b_2) * GE_{\text{triticale}}$$

Similar to the energy balance, nitrogen retention (RN) of birds were determined with a linear model where N intake of the test ingredient (x) was regressed on to the corresponding excretion of nitrogen (y). The complement of this slope, (1-b) * N content of the test ingredient, yielded an estimate of RN (g) per kg consumption of the test ingredient. This estimate was then used to calculate the nitrogen correction factor (NRCF) to determine the TME_n values of the various test ingredients. The same principles as outlined are applicable to the determination of TME_n for triticale in ostriches where a multiple regression was used for the estimation of RN from triticale and lucerne respectively.

The statistical analyses were performed by using General Linear Model (GLM) procedure of Statistical Analysis System (1985).

RESULTS

1. *AME_n values as determined directly for malting barley, oats, triticale and maize*

Dietary characteristics are given in Table 1 and results on feed intake and dry matter digestibilities (DMD), AME and AME_n are presented in Table 2 and Table 3 respectively.

Roosters showed significantly reduced feed consumptions for the higher fibre ingredients namely oats and barley as opposed to that of maize and triticale. Feed intake in ostriches decreased for the higher energy diets, with the exception of triticale. Triticale however was diluted with lucerne, causing increased levels of intake.

Improved DMD ($p<0.05$) were observed in ostriches for all the ingredients in comparison to that for roosters. The most profound difference was that for malting barley and triticale. Values of 0.826 and 0.797 were observed in ostriches for barley and triticale respectively while values of 0.659 and 0.670 were measured for roosters. The estimate for DMD of triticale in ostriches was calculated from the DMD of the test diet where triticale was substituted by 440 g/kg lucerne. The DMD of this diet was 0.667 ± 0.0128.

Ostriches showed improved ($p<0.05$) metabolisabilities for maize, malting barley, triticale and oats in comparison to that of roosters. The AME_n values for these ingredients were 14.21, 12.65, 14.89 and 12.60 MJ/kg. It was noted that ostriches receiving the triticale-lucerne test diet had a substantially high nitrogen retention of 25.8 g/day, causing a decline in the AME value of 11.45 ± 0.201 to 10.9 ± 0.178 for AME_n. This explains why AME for triticale, 13.16 MJ/kg is significantly reduced to 12.60 MJ/kg for AME_n.

As for DMD figures in roosters, AME_n values varied according to the fibre content in these ingredients. As evident from Table 1, maize was from a very good quality with a low moisture content, explaining the high AME_n value for roosters of 14.42 MJ/kg for maize. AME_n for triticale, malting barley and oats were 11.44, 11.06 and 10.48 MJ/kg respectively.

2. *TME_n values as determined by the regression method for malting barley, oats, triticale and maize.*

The slopes (b) of the regression lines relating excreta output to feed intake were significant for all the test ingredients for both ostriches and roosters (Table 4). These values were used to compute DMD values (Table 7) for the various ingredients
(1-b).

Similar DMD values (Table 7) as reported in Table 2 were calculated for most ingredients in roosters and ostriches by the regression method. Oats in ostriches however had a substantially lower DMD value of 0.637 in relation to 0.691 reported earlier by averaging individual measurements over birds.

The slopes of the energy balance relationships were all significant (Table 5) and were used for the calculation of TME values in Table 7. All intercepts were not significantly different from zero ($p>0.05$) for both ostriches and roosters so that no estimate of endogenous energy losses could be established.

For the correction of TME to TME_n values the N-balance equations (Table 6) were used. The slopes of the regression line relating N input to N excreted were not significant ($p>0.05$) for ostriches receiving malting barley, maize and triticale and for roosters consuming oats and triticale. Birds on these diets were therefore in N-balance ($RN=0$) so that $TME = TME_n$.

TME_n values of the various ingredients for roosters were in good agreement with AME_n values reported earlier in Table 3. These values were 11.33, 10.63, 14.07 and 11.82 MJ/kg for malting barley, oats, maize and triticale respectively. The corresponding TME_n values for ostriches were 13.92, 12.27, 15.22 and 13.21 MJ/kg.

DISCUSSION

The difference in TME_n values between ostriches and poultry for malting barley, oats, triticale and maize confirmed the previous work by Cilliers **et al.**(1994) that ostriches have the ability to utilise the fibrous components of plant materials. This was clear from the improved DMD observed for the various ingredients in ostriches.

The TME_n value of 15.22 MJ/kg for maize in ostriches, was in good agreement to the estimate of 14.9 MJ/kg reported by Cilliers **et al.**(1994). For the latter study maize was not supplied as a complete diet, but diluted with lucerne, resulting in higher levels of intake. The low level of maize intake of 770 g/bird/day in the present study might have caused that TME_n overestimated the true available energy content of maize.

For the determination of triticale in ostriches, lucerne was used as the basal diet to estimate the metabolisable energy content of triticale in the test diet. The TME_n for lucerne of 8.59 MJ/kg compared favourably with an estimate of 8.60 MJ/kg reported by Cilliers **et al.** (1994).

As no intercept ($p>0.05$) was computed for the energy balance regressions for all ingredients in ostriches and roosters, no estimation foe endogenous energy losses (EEL) could be established. These work confirmed earlier findings by Härtel (1986) and Johnson (1987) in roosters who concluded that EEL is a characteristic of the method of feeding. Farrell, Thomson,
Du Preez & Hayes (1991) explained that under continuous-feeding methods which was applied in the present study, levels of intake were to high for extrapolation to zero intake to obtain EEL.

Observed TME_n values for roosters viz. 11.33 MJ/kg, 10.63 MJ/kg, 14.07 MJ/kg and 11.82 MJ/kg of malting barley, oats, maize and triticale respectively corresponded well with published figures (Evans, 1985; Allen, 1990; Hayes & Du Preez, unpublished results). No published literature could be found for these ingredients in ostriches.

The improved energy values of the various energy sources for ostriches, proved that the non-starch polysaccharides in these more fibrous energy sources had no detrimental effect on the available energy of these ingredients. It is realised that the TME_n values of these ingredients will vary from batch to batch and that this should be monitored closely. The utilisation of these ingredients in diets for monogastric animals is mainly determined by its fibre contents and the levels of the non-starch polysaccharides, ß-glucans and arabinoxylans (Leterme, Tahon & Thewis, 1991; Best, 1993).

The determined TME_n values for ostriches of malting barley (13.92 MJ/kg), oats (12.27 MJ/kg), triticale (13.21 MJ/kg) and maize (15.22 MJ/kg) enable the economical use of various energy sources in diet formulation. As ostriches do not experience the anti-nutritive activities encountered by poultry in using the more fibrous ingredients like barley, oats and triticale, the cost of diets for these birds could markedly be reduced.

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TABLE 1: CHEMICAL COMPOSITION OF THE VARIOUS TEST INGREDIENTS

SOURCE	PROTEIN g/kg	MOISTURE g/kg
Barley	93.11	103.21
Oats	114.7	92.11
Yellow Maize	90.54	53.85
Lucerne	176.12	71.42
Triticale	136.31	69.01

TABLE 2: AVERAGE FEED INTAKE AND DRY MATTER DIGESTIBILITY (DMD) OF VARIOUS ENERGY SOURCES FOR ROOSTERS AND OSTRICHES

SOURCE	OSTRICHES	ROOSTERS
DMD		
Barley	0.826 ± 0.00559^{aA}	0.659 ± 0.00768^{B}
Oats	0.691 ± 0.00760^{bA}	0.597 ± 0.0178^{abB}
Maize	0.850 ± 0.0162^{aA}	0.826 ± 0.0024^{abcB}
Lucerne	0.501 ± 0.0121	-
Triticale *	0.797 ± 0.00597^{bA}	0.670 ± 0.0048^{abB}
FEED INTAKE (kg/day)		
Barley	1.256 ± 0.107^{adA}	0.074 ± 0.0091^{abB}
Oats	1.399 ± 0.117^{abdA}	0.054 ± 0.0085^{bB}
Maize	0.769 ± 0.129^{A}	0.085 ± 0.0030^{aB}
Lucerne	1.558 ± 0.142^{acdA}	-
Triticale	1.786 ± 0.144^{bcA}	0.088 ± 0.0049^{aB}

* Estimated by the replacement method

Estimates within the same column with common small letter superscripts, do not differ significantly ($p>0.05$)

Estimates within the same row with common capital letter superscripts, do not differ significantly ($p>0.05$)

TABLE 3: AVERAGE AME, RN AND AME_n ESTIMATES OF VARIOUS ENERGY SOURCES FOR ROOSTERS AND OSTRICHES

SOURCE	OSTRICHES	ROOSTERS
AME MJ/kg		
Barley	14.55 ± 0.142^{aA}	11.13 ± 0.133^{B}
Oats	12.97 ± 0.152^{cA}	10.49 ± 0.295^{aB}
Yellow Maize	15.00 ± 0.203^{dA}	14.57 ± 0.038^{B}
Lucerne	9.27 ± 0.257^{e}	-
Triticale*	13.16 ± 0.154^{fA}	11.55 ± 0.0657^{aB}
RN g/day		
Barley	11.7 ± 1.21^{cA}	0.179 ± 0.0665^{aC}
Oats	12.04 ± 1.11^{cA}	0.030 ± 0.0362^{abB}
Yellow Maize	3.53 ± 1.52^{A}	0.352 ± 0.0241^{bB}
Lucerne	23.03 ± 2.95^{ab}	-
Triticale*	28.00 ± 3.12^{aA}	0.262 ± 0.1060^{abB}
AME_n MJ/kg		
Barley	14.21 ± 0.138^{aA}	11.06 ± 0.119^{B}
Oats	12.65 ± 0.154^{cA}	10.48 ± 0.266^{aB}
Yellow Maize	14.89 ± 0.169^{dA}	14.42 ± 0.038^{B}
Lucerne	8.74 ± 0.278^{eA}	-
Triticale*	12.60 ± 0.149^{fA}	11.44 ± 0.0613^{aB}

* Estimated by the replacement method

[a] Estimates within the same column with common small letter superscripts, do not differ significantly ($p>0.05$)

Estimates within the same row with common capital letter superscripts, do not differ significantly ($p>0.05$)

TABLE 4: REGRESSION METHOD:

UNDIGESTIBLE PROPORTIONS OF VARIOUS ENERGY SOURCES FOR ROOSTERS AND OSTRICHES

SOURCE	INTERCEPT	SLOPE b_1	SLOPE b_2	R^2
OSTRICHES				
Barley	-26 ± 32 *	0.197 ± 0.0258	-	0.936
Oats	-72 ± 42 *	0.363 ± 0.0297	-	0.955
Maize	23 ± 32 *	0.114 ± 0.0392	-	0.680
Lucerne[a]	11 ± 67 *	0.490 ± 0.04127	-	0.909
Triticale[a]	11 ± 67 *	-	0.197 ± 0.0430	0.909
ROOSTERS				
Barley	2 ± 2 *	0.312 ± 0.0220	-	0.976
Oats	0 ± 5 *	0.397 ± 0.1070	-	0.873
Maize	- 1 ± 1 *	0.193 ± 0.0166	-	0.900
Triticale	0 ± 3 *	0.331 ± 0.0376	-	0.951

* Intercepts not significantly different from zero ($p>0.05$)

[a] Estimated simultaneously by multiple regression

TABLE 5: REGRESSION METHOD

THE UNMETABOLISABLE PROPORTIONS OF VARIOUS ENERGY SOURCES FOR ROOSTERS AND OSTRICHES

SOURCE	INTERCEPT	SLOPE b_1	SLOPE b_2	R^2
OSTRICHES				
Barley	-0.7 ± 0.901 *	0.191 ± 0.0411	-	0.843
Oats	-1.0 ± 0.970 *	0.319 ± 0.0394	-	0.903
Maize	0.12 ± 0.528 *	0.117 ± 0.0377	-	0.706
Lucerne[a]	-0.3 ± 1.18 *	0.455 ± 0.0444	-	0.885
Triticale[a]	-0.3 ± 1.18 *	-	0.204 ± 0.0459	0.885
ROOSTERS				
Barley	29 ± 36 *	0.328 ± 0.0273	-	0.966
Oats	- 1 ± 94 *	0.381 ± 0.1020	-	0.874
Maize	-28 ± 22 *	0.175 ± 0.0152	-	0.899
Triticale	20 ± 44 *	0.288 ± 0.0302	-	0.958

* Intercepts not significantly different from zero ($p>0.05$)

[a] Estimated simultaneously by multiple regression

TABLE 6: REGRESSION METHOD:

UNRETAINABLE NITROGEN PROPORTIONS OF VARIOUS ENERGY SOURCES FOR ROOSTERS AND OSTRICHES

SOURCE	INTERCEPT	SLOPE b_1	SLOPE b_2	R^2
OSTRICHES				
Barley	-1 $\pm$ 5.2 *	0.48 $\pm$ 0.275 *	-	0.430
Oats	-3 $\pm$ 3.8 *	0.659 $\pm$ 0.148	-	0.739
Maize	4 $\pm$ 2.6 *	0.323 $\pm$ 0.222 *	-	0.341
Lucerne[a]	5 $\pm$ 2.6 *	0.342 $\pm$ 0.103	-	0.500
Triticale[a]	-	-	0.119 $\pm$ 0.134 *	0.500
ROOSTERS				
Barley	0.31 $\pm$ 0.104	0.555 $\pm$ 0.0911	-	0.881
Oats	-0.1 $\pm$ 0.541 *	0.963 $\pm$ 0.264	-	0.872
Yellow Maize	0.0 $\pm$ 0.152 *	0.710 $\pm$ 0.122	-	0.692
Triticale	0.4 $\pm$ 0.767 *	0.626 $\pm$ 0.394 *	-	0.391

* Estimates not significantly different from zero ($p>0.05$)

[a] Estimated simultaneously by multiple regression

TABLE 7: THE DMD, RN, TME AND TME_n ESTIMATES OF VARIOUS ENERGY SOURCES FOR ROOSTERS AND OSTRICHES AS CALCULATED BY THE REGRESSION METHOD

SOURCE	DMD	g N/kg feed RN	MJ/kg TME	MJ/kg TME_n
OSTRICHES				
Barley	0.803 ± 0.0115	0*	13.92 ± 0.316	13.92 ± 0.316*
Oats	0.637 ± 0.0105	6.3 ± 0.961	12.50 ± 0.256	12.27 ± 0.291
Maize	0.886 ± 0.0175	0 *	15.22 ± 0.291	15.22 ± 0.291*
Lucerne	0.510 ± 0.0151	18.5 ± 1.026	9.26 ± 0.267	8.59 ± 0.304
Triticale	0.803 ± 0.0136	0 *	13.21 ± 0.241	13.21 ± 0.241*
ROOSTERS				
Barley	0.688 ± 0.0089	6.6 ± 0.442	11.57 ± 0.192	11.33 ± 0.212
Oats	0.603 ± 0.0479	0 *	10.63 ± 0.738	10.63 ± 0.783*
Maize	0.807 ± 0.0042	4.2 ± 0.442	14.22 ± 0.066	14.07 ± 0.082
Triticale	0.669 ± 0.0168	0 *	11.82 ± 0.224	11.82 ± 0.224*

* Birds were in N-equilibruim, hence TME = TME_n

CHAPTER 5

THE TRUE AND APPARENT METABOLISABLE ENERGY VALUES OF WHEAT BRAN AND LUCERNE AS DETERMINED FOR MATURE OSTRICHES (STRUTHIO CAMELUS) AND ROOSTERS.

BY

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ABSTRACT

In two experiments involving 24 mature ostrich males, AME_n and TME_n values of lucerne and wheat bran were determined by means of total collection method. These findings were compared to estimates for roosters. Significantly improved AME_n values for wheat bran viz. 11.72 MJ/kg were measured for ostriches in comparison to 8.01 MJ/kg for roosters. AME_n values of lucerne were 4.05 MJ/kg and 8.74 MJ/kg for roosters and ostriches respectively. TME_n values were determined by regression method and amounted to 11.91 MJ/kg and 8.55 MJ/kg for wheat bran in ostriches and roosters respectively. TME_n values for lucerne were 8.58 MJ/kg and 4.03 MJ/kg for ostriches and roosters respectively. Results in the present study confirmed previous findings by Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994) and Cilliers, Hayes, Chwalibog and Du Preez (1994b) that substantially improved metabolisabilities of feed ingredients are observed for ostriches as opposed to values used for diet formulation in poultry. It was concluded that the utilisation of wheat bran in diets for ostriches should be economically more feasible as its use in diets for poultry.

INTRODUCTION

Increased commercial farming with ostriches for meat and hide production requires efficient diet formulation for maximum profitability. Swart, Mackie and Hayes (1993) demonstrated the production of volatile fatty acids in the hind gut of ostriches and concluded that improved metabolisabilities of fibrous ingredients should be expected as the result of the digestibility of hemicellulose and cellulose in plant fibres. Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994) conducted a comparative study between roosters and ostriches with respect to the TME_n values of lucerne and determined markedly improved TME_n values of 8.6 MJ/kg for ostriches in comparison to 4.03 MJ/kg for poultry. These results

emphasised the importance of the evaluation of feedstuffs for ostriches for effective least cost diet formulation.

The steady trends to a more diversified and economical feed supply to non-ruminants for meat and egg production over the last few years, necessitate the need for the reduction of feed costs. This has resulted in the utilisation of alternative feeds to cereals namely industrial by-products like wheat bran that originated from the processing of grains for human consumption.

Wheat bran comprises of a mixture of the coarse outer covering of the wheat kernel, flour, some finely ground wheat seeds and other non-wheat components. Due to the bulky and fibrous nature of bran, dietary levels in high energy poultry diets are restricted and may be overpriced according to its nutritional value. Due to the fibre digestible capabilities of ostriches, the question arises whether it wouldn't be more economical for feed manufactures to use wheat bran in diets for ostriches rather than in diets for other monogastric animals.

As the cost of wheat bran often compares favourably to that of lucerne, estimates on the energy content of wheat bran can provide valuable information for deciding which if these ingredients will be the more profitable to use in diets for ostriches.

The paper therefore deals with a comparative study between roosters and mature ostriches with respect to the metabolisable energy values, corrected to zero nitrogen retention (AME_n and TME_n) for wheat bran. Results for wheat bran is compared to values determined with lucerne.

MATERIALS AND METHODS

Diets and Treatments

Wheat bran was warm-pelleted (6 mm) and used as such for test diet 1 in ostriches and roosters. Locally produced lucerne was hammermilled and cold pelleted (8 mm) to compile test diet 2 for the ostriches. TME_n and AME_n values of lucerne for roosters reported by Cilliers **et al** (1994a), were used for comparing values obtained for ostriches in the present study.

Animal Husbandry

The balance procedure as described by Cilliers **et al.,** (1994a) and Cilliers, Hayes, Chwalibog and Du Preez (1994b) for ostriches was applied where results were obtained by means of total excreta collection with harnesses in metabolism cages. The two test diets (lucerne and wheat bran) were distributed at

random among 24 mature ostrich males after an initial adaption period of 7 days. Feed intake and excreta production were accurately measured for the following 5 days. Test diets were provided at daily intake levels of 1500, 2000 and 2500 g/bird/day to enable an extended range of energy intakes for regression analises.

Wheat bran in roosters were fed according to the DSQ method described by Du Preez, Duckitt & Paulse (1986), where 12 individually housed roosters (Lohmann Brown laying strain) were fasted for 20 hours, followed by a feeding period of 4 days. Feed intake and excreta output were accurately measured over the last 3 days. Daily intakes were restricted at 80, 110 and 140 g/bird to enable an extended range of energy intakes.

Analytical Procedures

Daily excretions were kept separate and stored at - 10°C, then dried in a forced draft oven at 80 °C to constant weight, whereafter constant weight with atmospheric moisture was allowed. Dry samples of daily voidings for individual birds were then proportionally pooled over days and used for analysis. The finely ground samples was used for nitrogen analysis, using the macro-Kjeldahl procedure and gross energy (GE) was estimated by using a solid state bomb calorimeter (Model CP 500, Digital Data Systems, P.O. Box 35872, Northcliff, Johannesburg.)

Calculation and statistical analysis of results

All results were directly computed and compared to results determined by regression method, as explained by Cilliers **et al.,** (1994a; 1994b). Excreta output, GE excretion and nitrogen (N) excretion were regressed to the corresponding levels of feed intake, GE intake and N-intakes respectively. The slopes of these linear regressions were then used for the calculation of dry matter digestibility (DMD), TME (MJ/kg) and N-retention (g N/kg diet). The latter were then used for the correction of TME to zero N-retention (TME_n) by using the factor of 36.5 kJ/g N retained.

RESULTS

1. *AME_n values as determined directly for wheat bran and lucerne*

Results are presented in Table 2. Markedly reduced feed intakes (average of 1293 g per day) of wheat bran was observed for ostriches in relation to average values of 1558 g measured for lucerne. The less bulkiness of wheat bran however caused higher levels of intake (81 g/day) as apposed to lucerne for roosters.

The DMD of wheat bran for roosters (0.436) was significantly improved to 0.605 when fed to ostriches. DMD values of lucerne for ostriches and roosters were 0.501 and 0.118 respectively. The enhanced digestibility of wheat bran by ostriches resulted in an AME value of 12.24 MJ/kg while 8.17 MJ/kg was determined for roosters. After the deduction of the energy equivalent for retained nitrogen, AME_n values were calculated as 11.72 MJ/kg and 8.01 MJ/kg for ostriches and roosters respectively. AME_n values of lucerne amounted to 8.74 MJ/kg for ostriches and 4.05 MJ/kg for roosters.

2. *TME_n values as determined for wheat bran and lucerne by regression method.*

The slopes of the linear regressions representing the indigestible, unmetabolisable energy and unretainable N fractions of wheat bran and lucerne for roosters and ostriches are given in Table 1. All slopes were statistically significant ($p<0.05$) and data represented straight lines with good fits (R^2). The complement of the indigestible proportions yielded estimates for DMD for wheat bran of 0.616 for ostriches and 0.463 for roosters (Table 3). DMD values of lucerne were 0.108 and 0.521 for roosters and ostriches respectively. These values compared favourably to the direct determinations reported earlier in Table 2.

As evident from the improved DMD of wheat bran for ostriches, significant higher TME values of 12.46 MJ/kg was computed to the 8.81 MJ/kg observed for roosters. For lucerne, TME values amounted to 9.21 MJ/kg and 4.26 MJ/kg for ostriches and roosters respectively. Considerably higher levels of N retention (g N/kg wheat bran consumed) were observed for ostriches as apposed to roosters viz. 15.1 g to 7.1 g. Similar N retention was measured for lucerne in ostriches, indicating that protein from wheat bran and lucerne were equally utilised. Using these values for the correction of the TME content in wheat bran to N-equilibrium, yielded values of 11.91 MJ/kg and 8.55 MJ/kg for ostriches and roosters respectively. TME_n values of lucerne for ostriches and roosters amounted to 8.58 MJ/kg and 4.03 MJ/kg. TME_n values of wheat bran and lucerne were in good agreement with AME_n values reported earlier in Table 2.

Intercepts of the regressions representing energy balance were not significantly different from zero ($p>0.05$), hence no estimation of endogenous energy losses could be established.

DISCUSSION

Large variation is observed in literature values for AME_n for wheat bran in roosters (Allen, 1992; Evans, 1985; Farrell, Thomson; Hayes & Du Preez, 1991; Gous & Dennison, 1983). AME_n and TME_n values of 8.01 MJ/kg and 8.55 MJ/kg computed in the present study, however are in agreement to the findings of Gous **et al.,** (1993). The markedly enhanced TME_n and AME_n values of wheat bran viz. 11.91 MJ/kg

and 11.72 MJ/kg for ostriches confirmed expectations of improved metabolisabilities due to fibre digestible capabilities.

AME_n and TME_n values of lucerne for ostriches viz. 8.74 MJ/kg and 8.58 MJ/kg in the present study compared favourably to the findings of Cilliers **et al.**, (1994a; 1994b).

The inability of estimating endogenous energy losses (EEL) due to the fact that all intercepts for lucerne and wheat bran in roosters and ostriches were not different from zero, were in agreement to the findings of Härtel (1986). Härtel (1986) concluded that with continuous feeding, should there be little difference between AME_n and TME_n values. AME_n and TME_n values of lucerne and wheat bran for both roosters and ostriches in the present study, confirmed these findings as all experimental diets were offered at a continuous feeding basis.

Results on the TME_n value of 11.91 MJ/kg for wheat bran, indicate that wheat bran could make a substantial energy contribution to diets for ostriches and should its utilisation in diets be preferable to lucerne where comparable prises are involved. If limit quantities of wheat bran are available for feed manufacturing, it would be more cost effective to use wheat bran in diets for ostriches than in diets for poultry.

The improved metabolisabilities observed in the present study for ostriches as opposed to poultry, emphasised the importance for the complete evaluation of all feedstuffs for ostriches to enable cost effective diet formulation.

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TABLE 1: THE INDIGESTIBLE, UNMETABOLISABLE AND UNRETAINABLE N PROPORTIONS OF WHEAT BRAN AND LUCERNE FOR ROOSTERS AND OSTRICHES AS DETERMINED BY REGRESSION

	Digestibility	Energy balance	N - retention
OSTRICHES			
Wheat bran			
Intercept	13 ± 48 *	0.64 ± 0.664 *	1 ± 4.5 *
Slope	0.384 ± 0.0363	0.297 ± 0.0282	0.429 ± 0.131
R^2	0.941	0.934	0.607
Lucerne			
Intercept	28 ± 78 *	-0.1 ± 1.6 *	3.9 ± 6.9 *
Slope	0.479 ± 0.0487	0.458 ± 0.0589	0.386 ± 0.156
R^2	0.933	0.896	0.500
ROOSTERS			
Wheat Bran			
Intercept	2 ± 3 *	46 ± 84 *	0.2 ± 0.262 *
Slope	0.537 ± 0.0497	0.503 ± 0.0571	0.732 ± 0.119
R^2	0.936	0.907	0.826
Lucerne [a]			
Intercept	0.02 ± 0.015 *	0.3 ± 0.0464 *	0.34 ± 0.113
Slope b_1	0.177 ± 0.0104	0.158 ± 0.0103	0.44 ± 0.0948
Slope b_2	0.892 ± 0.0173	0.754 ± 0.0166	0.41 ± 0.0715
R^2	0.993	0.991	0.525

* Estimates marked ' * ' do not differ from zero ($p>0.05$)

[a] Estimated by multiple regression where b_1 = maize and b_2 = lucerne.

Level of lucerne in the test diet was 500 g/kg. Results taken from Cilliers **et al.**, (1994a)

TABLE 2: DIET COMPOSITION, FEED INTAKE, DMD, AME, RN AND AME_n ESTIMATES OF WHEAT BRAN AND LUCERNE FOR ROOSTERS AND OSTRICHES

	WHEAT BRAN		LUCERNE	
Chemical composition				
Protein, g/kg	164.96		176.12	
Moisture, g/kg	90.67		66.51	
	Roosters	**Ostriches**	**Roosters** [a]	**Ostriches**
Feed intake, g/bird/day	81 ± 0.0080	1293 ± 0.120	49 ± 5.89	1558 ± 142
DMD	0.436 ± 0.0170	0.605 ± 0.00923	0.118 ± 0.0111	0.501 ± 0.0121
AME, MJ/kg	8.17 ± 0.304	12.24 ± 0.126	4.44 ± 0.200	9.27 ± 0.257
RN, g/day	0.365 ± 0.091	18.72 ± 2.10	0.64 ± 0.227	23.03 ± 2.95
AME_n, MJ/kg	8.01 ± 0.269	11.72 ± 0.113	4.05 ± 0.321	8.74 ± 0.278

[a] Results taken from Cilliers **et al.**, (1994a)

TABLE 3: THE DMD, RN, TME AND TME_n ESTIMATES OF WHEAT BRAN AND LUCERNE FOR ROOSTERS AND OSTRICHES AS DETERMINED BY REGRESSION METHOD

	WHEAT BRAN		LUCERNE	
	Roosters	**Ostriches**	**Roosters**[a]	**Ostriches**
DMD	0.463 ± 0.0166	0.616 ± 0.0128	0.108 ± 0.00654	0.521 ± 0.0184
RN, g N/kg feed	7.1 ± 1.05	15.1 ± 1.21	6.22 ± 1.25	17.3 ± 1.66
TME, MJ/kg	8.81 ± 0.337	12.46 ± 0.177	4.26 ± 0.109	9.21 ± 0.378
TME_n, MJ/kg	8.55 ± 0.375	11.91 ± 0.221	4.03 ± 0.118	8.58 ± 0.439

[a] Results taken from Cilliers **et al.**, (1994a)

CHAPTER 6

A COMPARATIVE STUDY BETWEEN YOUNG AND MATURE OSTRICHES (STRUTHIO CAMELUS) WITH RESPECT TO THE TRUE AND APPARENT METABOLISABLE ENERGY VALUES FOR LUCERNE AND BARLEY

BY

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ABSTRACT

A comparative study was conducted between ostriches, six months and mature, with respect to the true and apparent metabolisable energy contents, corrected to N-equilibrium, for lucerne hay and malting barley. Similar AME_n values for lucerne were determined for the young and mature birds viz. 9.17 MJ/kg and 8.97 MJ/kg. These values compared favourably to TME_n estimates of 9.16 MJ/kg and 9.26 MJ/kg. AME_n values of malting barley were 14.24 MJ/kg and 14.21 MJ/kg for the young and mature ostriches respectively. The congruent TME_n estimates were 13.94 MJ/kg and 13.92 MJ/kg.
None of these estimates differed significantly between the two age groups. It was concluded that AME_n and TME_n values determined for mature ostriches will be suitable for the formulation of diets for ostriches of six months and older.

INTRODUCTION

Considerable evidence exist that the apparent metabolisable energy content (AME) of feed ingredients vary between young and mature poultry (Johnson, 1987) so that separate sets of energy values are recommended for broilers, pullets and mature birds. This would be beneficial for efficient diet formulations.

A number of studies showed that the AME content of ingredients increased as chickens mature and that significantly improved values of the same ingredients, are reported for adult poultry (e.g. Zelenka, 1968; Peterson, Meyer & Sauter, 1976; Engster, Snetsinger, Kessler, 1981; Farrell, Thomson, Choice, Asches, Peck & Hogan, 1983; Sibbald, 1982; Johnson, 1987 Farrell, 1991). This difference was more crucial for

ingredients containing high levels of fibre, fat and non-starch polysaccharides viz. pentosans, ß-glucans and arabinoxylan (Sibbald, 1982; Johnson, 1987; Annison & Johnson, 1989).

Recent studies by Cilliers, Hayes, Chwalibog and Du Preez (1994a), showed significantly improved AME_n and TME_n values for malting barley, triticale and oats in comparison to congruent estimates for adult roosters. Cilliers **et al.,** (1994a) concluded that the non-starch polysaccharide in these grains had little effect on the digestibility of these grains by mature ostriches. The substantially higher AME_n and TME_n values of lucerne viz. 8.9 MJ/kg and 8.6 MJ/kg reported by Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994b) for mature ostriches vs. 4.05 MJ/kg and 4.03 MJ/kg measured for adult roosters, emphasised the importance of the complete evaluation of feed ingredients for ostriches.

According to the findings and experience in the poultry industry on differences in energy values for young and mature poultry, raises the question whether the same principle will be applicable to ostriches.

This paper deals with a comparative study between young and mature ostriches, with respect to the true and apparent metabolisable energy content, corrected to nitrogen equilibrium (TME_n and AME_n), for lucerne hay and malting barley. Results on these findings will determine whether separate sets of values are required for ostriches in various stages of maturity.

MATERIALS AND METHODS

Diets and Treatments

Locally produced lucerne hay, hammermilled through a 12 mm sieve and malting barley were used as such to compile the two test diets. Both ingredients were cold pelleted (8 mm) to minimise feed spillage.

Animal Husbandry

To be able to use the available facilities, 24 mature ostrich males (30 months of age weighing between 110 and 120 kg) were compared with only one age group of 24 younger ostriches (6 months of age, weighing between 50 and 60 kg). The sex of the younger birds were at this age still unknown.

The balance procedure as described by Cilliers **et al.,** (1994a) and Cilliers **et al.,**(1994b) for ostriches was applied where results were obtained by means of total excreta collection with harnesses in metabolism cages. As the mature ostriches were accustomed to the handling procedures, considerable

time and effort were put into training the younger chicks. This took 2 weeks after which these birds were ready for experimentation.

The two test diets (lucerne and malting barley) were distributed at random among the experimental birds, after an initial adaption period of 7 days. Feed intake and excreta output were accurately measured for the following 5 days. Test diets were provided at daily intake levels of 1500, 2000 and 2500 g/bird for mature birds and 500, 1000 and 1500 g/bird for the chicks. This was to enable an extended range of energy intakes for regression analises.

Analytical Procedures

Daily excretions were kept separate and stored at - 10°C, then dried in an forced draft oven at 80 °C to constant weight, whereafter constant weight with atmospheric moisture was allowed for 24 hours. Dry samples of daily voidings for individual birds were then proportionally pooled over days, finely ground and used for analysis. Gross energy (GE) was estimated by using a solid state bomb calorimeter (Model CP 500, Digital Data Systems, P.O. Box 35872, Northcliff, Johannesburg.). Nitrogen (N) analysis were performed by the macro-Kjeldahl procedure.

Calculation and statistical analysis of results

As the test ingredients were used as sole dietary components in the test diets, results could directly be computed that yielded values for AME and AME_n. For the correction of AME to AME_n, the factor of 36.5 kJ/g N retained (RN) were used.

These results were also compared to estimates determined by regression method as explained by Cilliers **et al.,** (1994a; 1994b). Excreta output, GE excretion and N-excretion were regressed to the congruent levels of feed consumption, GE intake and N-intake. The complement of the slopes for these linear regressions were then used for the calculation of dry matter digestibility (DMD), TME (MJ/kg) and N-retention (g N/kg diet). With an estimate for RN per kg of test ingredient consumed, TME was accordingly adjusted to TME_n. Results were calculated and evaluated using the GLM option of the SAS Institute (1985).

RESULTS

1. *AME_n values for lucerne and malting barley.*

Results on average feed intake, DMD, AME, AME_n of lucerne and barley for chicks and mature birds are presented in Table 1 and Table 4.

Similar DMD values viz. 0.529 and 0.519 were measured for lucerne in young and mature birds. AME values amounted to 9.92 MJ/kg and 9.54 MJ/kg for chicks and mature birds respectively. After correction to N-equilibrium, AME_n values were computed as 9.17 MJ/kg and 8.97 MJ/kg.

As for lucerne, comparable DMD figures were observed for barley between young and mature birds (0.805 vs. 0.826). Identical AME values were also determined at 14.55 MJ/kg. After RN was taken into calculation, these values were altered to 14.24 MJ/kg and 14.21 MJ/kg to yield values for AME_n.

No statistical difference ($p>0.05$) was computed between the two experimental age groups with respect to DMD, AME and AME_n values for lucerne and barley.

2. *TME_n values for lucerne and malting barley as determined by regression method.*

The various regressions for lucerne and barley, representing digestibility, energy balance and N retention, are given in Table 2 and Table 5. All the intercepts in these models were found to be to statistically different from zero ($p>0.05$).

For lucerne, all slopes were significant and measurements were distributed proportionally around the straight line. The complement of the digestibility slopes, yielded DMD values of 0.552 and 0.530 for chicks and mature birds respectively. The congruent TME values were calculated as 9.75 MJ/kg and 9.88 MJ/kg. Similar RN estimates of 16.07 g N/kg and 16.84 g N/kg lucerne consumed, were observed for the two age groups, resulting in comparable TME_n values of 9.16 MJ/kg and 9.26 MJ/kg. These results are given in Table 3.

DMD figures of 0.825 and 0.803 for young and mature birds, determined by regression method (Table 5), were in good agreement with direct calculations reported earlier in Table 4. Markedly reduced TME values of 14.28 MJ/kg and 13.93 MJ/kg were observed for the two age groups in relation to AME values (Table 6). Mature ostriches, receiving the barley test diet, were in N-balance, according to the non significant slope ($p>0.05$) computed for them, hence the TME_n value of 13.92 MJ/kg was equal to the TME measurement. After the correction of TME to zero N- retention, TME_n of barley for the young birds

was estimated at 13.94 MJ/kg. These values were in good agreement to AME_n values reported earlier in Table 4. As for lucerne, no statistical difference was observed for any of the barley parameters (DMD, AME, AME_n, TME and TME_n) between young and mature ostriches.

As no intercept was significantly different from zero in the regression models of energy balance for lucerne and barley in both age groups, no estimation of endogenous energy losses (EEL), could be established.

DISCUSSION

The sensitivity of AME measurements to variations in feed intake is thoroughly described in literature (e.g. McNab, 1990). AME will depend on the EEL per unit of feed intake and according to Sibbald (1982), this explained the observed difference in AME values between young and mature birds. Jonsson and McNab (1983) also confirmed this statement by proving that the lower energy values of ingredients for younger chicks, especially the more fibrous ingredients, was caused by the depressed feed intake. The methodology of determining energy values of ingredients however may also have a significant effect on age differences (Johnson, 1987).

Due to the inexperience of feedstuff evaluation with ostriches and the despirate attempt to obtain reliable energy values for feed ingredients, the conventional method of continuous feeding were used for the estimation of the AME_n and TME_n values of lucerne and barley.

As the intercepts of barley and lucerne for the relationship between GE excreted and GE consumed for young and mature ostriches, were not statistically different from zero, no estimate for EEL could be established. This clearly showed that AME in the present study was not effected by levels of feed intake. It would therefore be expected for AME_n and TME_n values to be closely comparable and this were confirmed by the results in the present study. Similar findings by Johnson (1987) with young and older broilers were explained as the result of the continuous feeding method.

Swart, Mackie and Hayes (1993), conducted a comparative study between three weight groups (5-10 kg; 15-18 kg; 42-50 kg) of ostrich chicks with respect to the AME content of a complete diet, consisting of maize, lucerne, fish meal and vitamin-minerals. The AME content of this diet decreased from 12.85 ± 0.2 MJ/kg, 12.28 ± 0.1 MJ/kg to 11.84 ± 0.6 MJ/kg as the diet was offered to older birds. The estimate for the younger chicks was significantly higher with respect to the value reported for the middel weight group. Great variation in the AME measurement for the older group caused that the lower estimate did not differ from the two younger groups. These findings are confusing as no correction for RN was applied. One would have expected substantially higher N retentions (g N/kg diet consumed)

for the younger birds. If this was taken into account, the AME_n values could have been comparable.

The consistent higher in between bird variation observed for the younger ostriches, for both lucerne and barley, was probably the result of a higher degree of stress experienced in the metabolism crates, while mature birds were more accustomed to the crates and collection procedures.

Results in the present study clearly indicate that AME_n and TME_n values for mature ostriches are suitable for the formulation of diets for ostriches from six months upwards. Future research will have to determine whether mature AME_n and TME_n values will also be applicable to younger birds.

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TABLE 1: DIETARY COMPOSITION AND AME_n VALUES OF LUCERNE FED TO YOUNG AND MATURE OSTRICHES

	Young ostriches	Mature ostriches
Moisture g/kg	47.35	
Gross energy kJ/g	17.011	
Protein g/kg	198.53	
Feed intake g/day/bird	868 ± 79.9	1601 ± 153
DMD	0.529 ± 0.0199	0.519 ± 0.0106
AME MJ/kg	9.92 ± 0.281	9.54 ± 0.227
RN g/day/bird	17.58 ± 1.57	24.7 ± 2.71
AME_n MJ/kg	9.17 ± 0.251	8.97 ± 0.226

TABLE 2: THE INDIGESTIBLE, UNMETABOLISABLE AND UNRETAINABLE N-PROPORTIONS OF LUCERNE FED TO YOUNG AND MATURE OSTRICHES

	Digestibility	Energy balance	N-retention
YOUNG OSTRICHES			
Intercept	3 ± 72*	-0.1 ± 0.997*	-3 ± 3.80*
Slope	0.448 ± 0.0808	0.427 ± 0.0656	0.494 ± 0.134
R^2	0.815	0.858	0.660
MATURE OSTRICHES			
Intercept	47 ± 89*	0.85 ± 1.57*	-0.8 ± 6.33*
Slope	0.470 ± 0.0540	0.419 ± 0.0548	0.470 ± 0.137
R^2	0.927	0.907	0.661

* Estimates not different from zero ($p > 0.05$)

TABLE 3: THE DMD, TME AND TME_n VALUES OF LUCERNE FED TO YOUNG AND MATURE OSTRICHES AS ESTIMATED BY REGRESSION METHOD

	Young ostriches	Mature ostriches
DMD	0.552 ± 0.0286	0.530 ± 0.0204
RN g N/kg diet	16.07 ± 1.51	16.84 ± 1.645
TME	9.75 ± 0.395	9.88 ± 0.352
TME_n	9.16 ± 0.450	9.26 ± 0.412

TABLE 4: DIETARY COMPOSITION AND AME_n VALUES OF MALTING BARLEY FED TO YOUNG AND MATURE OSTRICHES

	Young ostriches	Mature ostriches
Moisture g/kg	103.21	
Gross energy kJ/g	17.2095	
Protein g/kg	93.11	
Feed intake g/bird/day	763 ± 107	1256 ± 101
DMD	0.805 ± 0.0127	0.826 ± 0.00559
AME MJ/kg	14.55 ± 0.142	14.55 ± 0.140
RN g/day/bird	6.69 ± 1.29	11.7 ± 1.21
AME_n MJ/kg	14.24 ± 0.136	14.21 ± 0.134

TABLE 5: THE INDIGESTIBLE, UNMETABOLISABLE AND UNRETAINABLE N-PROPORTIONS OF MALTING BARLEY FED TO YOUNG AND MATURE OSTRICHES

	Digestibility	Energy balance	N-retention
YOUNG OSTRICHES			
Intercept	29 ± 18*	-0.3 ± 0.588*	0.9 ± 0.645*
Slope	0.175 ± 0.0257	0.170 ± 0.0487	0.370 ± 0.0616
R^2	0.920	0.752	0.900
MATURE OSTRICHES			
Intercept	-26 ± 32*	-0.7 ± 0.901*	-1 ± 5.2*
Slope	0.197 ± 0.0258	0.191 ± 0.0411	0.48 ± 0.275*
R^2	0.936	0.843	0.430

* Estimates are not different from zero ($p > 0.05$)

TABLE 6: THE DMD, TME AND TME_n VALUES OF MALTING BARLEY FED TO YOUNG AND MATURE OSTRICHES

	Young ostriches	Mature ostriches
DMD	0.825 ± 0.0115	0.803 ± 0.0115
RN gN/kg DIET	9.4 ± 0.410	0*
TME	14.28 ± 0.375	13.92 ± 0.316[a]
TME_n	13.94 ± 0.390	13.92 ± 0.316[a]

[a] Birds were in N-balance, TME = TME_n

CHAPTER 7

A COMPARATIVE STUDY BETWEEN ROOSTERS AND MATURE OSTRICHES WITH RESPECT TO THE TRUE AND APPARENT METABOLISABLE ENERGY CONTENTS OF SOYBEAN OILCAKE MEAL AND SUNFLOWER OILCAKE MEAL

BY

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ABSTRACT

This paper deals with a comparative study between mature ostriches (Struthio Camelus) and adult roosters with respect to the true and apparent metabolisable energy contents, corrected for N-retention (AME_n and TME_n), of soybean oilcake meal (SBOKM) and sunflower oilcake meal (SFOCM). In Experiment 1, lucerne was used as a basal diet (1000 g/kg) for ostriches and used for the dilution of SBOCM to compile test diet 1 (400 g/kg SBOCM) and test diet 2 (600 g/kg SBOCM). For roosters, maize was offered as a basal diet and used to substitute SBOCM in test diets so that test diet 1 and test diet 2, contained 300 g/kg and 600 g/kg of SBOCM, respectively. In Experiment 2, SFOCM was used as such to compile the only test diet for both ostriches and roosters. Experimental diets were allotted at random to 12 ostriches and 10 roosters per test diet. The balance procedure for metabolisable energy evaluations with ostriches as described by Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994a) and Cilliers, Hayes, Chwalibog and Du Preez (1994b) were used. The DSQ-method of Du Preez, Duckitt and Paulse were used for estimations with poultry. AME_n values were determined by the replacement method and TME_n were calculated according to regression method as explained by Cilliers **et al.,** (1994a; 1994b).

Significantly improved digestibilities were observed for SBOCM and SFOCM in ostriches as opposed to values measured for roosters. AME_n values of lucerne in ostriches was 9.16 MJ/kg and values of 15.58 MJ/kg and 14.54 MJ/kg were accordingly calculated for SBOCM at the 400 g/kg and the 600 g/kg levels of substitution. In roosters, maize yielded AME_n values of 14.37 MJ/kg that were used to compute values of 9.33 MJ/kg and 9.20 MJ/kg for SBOCM at the 300 g/kg and 600 g/kg levels of substitution. Multiple regression yielded TME_n estimates of 8.84 MJ/kg for the lucerne basal diet and 13.44 MJ/kg for SBOCM in ostriches. As for SBOCM, markedly reduced AME_n values viz. 8.30 MJ/kg were observed

for SFOCM in roosters vs. measurements of 10.52 MJ/kg observed for ostriches. Similar TME_n values were calculated by regression method that yielded estimates of 10.79 MJ/kg and 8.89 MJ/kg for ostriches and roosters respectively.

Results in the present study confirmed the previous findings of Cilliers **et al.,** (1994a; 1994b), that significantly improved energy values are observed for ostriches in comparison to those used in diet formulation for the poultry and swine industries. It is concluded that the energy content of the plant protein sources, SBOCM and SFOCM, would make a substantial contribution to the energy value of diets for ostriches, hence reducing the required levels of energy sources in these diets.

INTRODUCTION

Soybean oilcake meal (SBOCM) is by far the most important plant protein source used in the poultry and swine industry today. Sunflower oilcake meal (SFOCM), with its less favourable amino acid pattern and higher fibre content, discourages its use in poultry and swine diets, in relation to that of SBOCM. The general dilemma experienced by the monogastric animal feeding industry, is that both these protein supplements are byproducts of the oil expressing industry and deficiencies in these products are often encountered. Hence, available sources should be efficiently distributed between the various commodities of the feed industry. This will ensure cost effective utilisation of available dietary components. For the optimal use of available dietary constituents, accurate information of the nutritive values of feed ingredients are required.

Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994a) and Ciliers, Hayes, Chwalibog and Du Preez (1994b; 1994c) showed the wasteful usage of ingredients in diets for ostriches formulated according to standards based on poultry and swine nutritional values, as suggested by Swart and Kemm (1985); Swart, Mackie and Hayes (1993). Significant improved values were reported for ostriches vs. that for poultry with respect to the TME_n and AME_n values of lucerne, barley, oats, triticale, maize and wheat bran. With these improved metabolisabilities observed for ostriches, the question regarding the energy content of the more popular plant protein sources viz. SFOCM and SBOCM, should be answered ?

This paper deals with a comparative study between adult roosters and mature ostriches with respect to the true and apparent metabolisable energy content, corrected to N-equilibruim, of sunflower oilcake meal and soybean oilcake meal.

MATERIALS AND METHODS

Diets and Treatments

Two separate sets of experiments were conducted in which SBOCM and SFOCM were individually evaluated with ostriches and then with roosters.

Ostriches

Three combinations of SBOCM and locally produced lucerne hay were used to compile test diets for energy evaluations in ostriches (Experiment 1):

Group 1: received lucerne as a basal diet (1000 g/kg)
Group 2: received test diet 1 consisting of 400 g/kg SBOCM and 600 g/kg lucerne
Group 3: received test diet 2 consisting of 600 g/kg SBOCM and 400 g/kg lucerne

The lucerne hay in these diets, were hammermilled through a 6 mm sieve. The complete diets were then cold pelleted (8 mm) to minimise wastage.

SFOCM was used as sole dietary component (1000 g/kg) to compile the test diet for ostriches in Experiment 2. SFOCM was received in pelleted-form (8 mm), hence it was decided to us it as such and not to dilute it with lucerne as for SBOCM.

Roosters

Three combinations of SBOCM were used for test diets in roosters in Experiment 1:

Group 1: received yellow maize as basal diet (1000 g/kg)
Group 2: received test diet 1 consisting of 300 g/kg SBOCM and 700 g/kg maize
Group 3: received test diet 2 consisting of 600 g/kg of SBOCM and 400 g/kg of maize.

SFOCM was used as such to compile the only test diet in Experiment 2. As SFOCM was not diluted by a basal ingredient for ostriches, it was decided to evaluate SFOCM under the same circumstances in roosters.

Animal Husbandry

Ostriches

The balance procedure for metabolisable energy evaluations as described by Cilliers **et al.,** (1994a; 1994b) for ostriches was applied where results were obtained by means of total excreta collection with harnesses in metabolism cages. Mature ostrich males (30 months of age) weighing between 110 and 120 kg were accustomed to the handling procedures and metabolism crates, which made them suitable for experimentation.

In Experiment 1, the three test diets were allotted at random to 36 experimental birds, while in Experiment 2, the SFOCM diet were distributed at random between 12 birds. In both trials an adaption period to the new diets of 7 days were allowed, while feed intake and excreta collection were accurately measured for the successive 5 days. Test diets were provided at daily intake levels of 1500, 2000 and 2500 g/bird to enable an extended range of energy intakes for regression analises.

Roosters

Test diets in Experiment 1 and Experiment 2 were evaluated according to the DSQ-method of Du Preez, Duckitt & Paulse (1986). A group of ten adult roosters (Lohmann Brown laying strain) were used per test diet. Roosters were starved for 20 hours, followed by a 24 hour adaption to the new test diets. Test diets were then offered for a period of 3 days in which daily intakes were restricted at 80, 110 and 140 g/bird. Feed consumption and excreta output were measured over the latter 72 hour period.

Analytical Procedures

Daily excretions were kept separate and stored at - 10°C until the termination of trials. Excreta were dried in a forced draft oven at 80 °C to constant weight and allowed to equilibrate with atmospheric moisture for 24 hours. Dry daily voidings of individual birds were then proportionally pooled over days, finely ground and used for analysis. Gross energy (GE) was estimated by using a solid state bomb calorimeter (Model CP 500, Digital Data Systems, P.O. Box 35872, Northcliff, Johannesburg.). Nitrogen (N) analysis were performed by the macro-Kjeldahl procedure.

Calculation and statistical analysis of results

In Experiment 1 where SBOCM was proportionally diluted by lucerne (for ostriches) and maize (for roosters), estimates for SBOCM (1000g/kg) were calculated according to the replacement method, explained by Cilliers **et al.,** (1994a). In Experiment 2 where SFOCM was used as sole dietary component in the test diet, results could directly be computed that yielded values for AME and AME_n. For the correction of AME to AME_n, the factor of 36.5 kJ/g N retained (RN) were used.

These results were also compared to estimates determined by regression method as explained by Cilliers **et al.,** (1994a; 1994b). In Experiment 1, a multiple regression ($Y = a + b_1X_1 + b_2X_2$) were applied where X_1 represent the contribution from the basal ingredient and X_2 represent the contribution from the test ingredient viz. SBOCM. In Experiment 2, where SFOCM was fed as a complete diet, a simple linear regression analysis was performed. Regression equations represented the following:

Digestibility: Excreta production (Y variable) vs. feed intake
Energy balance: Energy excreted (Y variable) vs. energy intake
Nitrogen retention: N-excreted (Y variable) vs. N-intake

The complement of these slopes were then used for the calculation of dry matter digestibility (DMD), TME (MJ/kg) and N-retention (g N/kg diet). With an estimate for RN per kg of test ingredient consumed, TME was accordingly adjusted to TME_n. Results were calculated and evaluated using the GLM option of the SAS Institute (1985).

RESULTS

1. *AME_n values of SBOCM as determined by the Replacement method*

Dietary characteristics and results of the SBOCM test diets for roosters and ostriches are given in Table 1. DMD, AME and AME_n values of the test diets for ostriches increased as levels of lucerne substitution in these diets declined. For roosters however where maize was used as the basal diet, DMD, AME and AME_n values steady decreased as inclusion levels of SBOCM were raised in test diets.

By using the DMD estimate of lucerne for ostriches viz. 0.501, DMD values of 0.718 and 0.756 were computed for SBOCM at the 400 g/kg and 600 g/kg level of substitution (Table 3) . The congruent AME values for this DMD figures amounted to 9.69 MJ/kg for lucerne and 16.61 MJ/kg and 15.69 MJ/kg for SBOCM. By applying the appropriate correction for N-retention (RN), AME_n values were estimated as

9.16 MJ/g, 15.58 MJ/kg and 14.54 MJ/kg for lucerne, SBOCM at 400 g/kg level and SBOCM at the 600 g/kg level respectively.

DMD values of 0.346 and 0.393 were calculated for SBOCM in roosters at the 300 g/kg and the 600 g/kg levels, with a DMD value of 0.836 for maize (Table 1 and Table 3). By using the AME value (14.51 MJ/kg) of maize, similar values of 9.34 MJ/kg and 9.38 MJ/kg were computed for SBOCM at the two levels of substitution. AME_n values of 9.33 MJ/kg and 9.20 MJ/kg were calculated for SBOCM, when the corresponding value of maize viz. 14.37 MJ/kg was applied.

2. *TME_n values for lucerne and SBOCM in ostriches and maize and SBOCM in roosters as determined by multiple regression method*

All the slopes representing the indigestible, unmetabolisable energy and unretainable N proportions were significant for lucerne and SBOCM (Table 2) in ostriches. For roosters however, the slope for RN of maize were not significant, indicating that roosters receiving maize were in N-equilibruim (Table 2). All intercepts for the energy balance relationships were found to be zero, hence no estimate of endogenous energy losses (EEL) could be established.

DMD values amounted to 0.490 and 0.726 for lucerne and SBOCM in ostriches and 0.846 and 0.393 for maize and SBOCM in roosters (Table 3). By using the gross energy values of lucerne, SBOCM and maize, the appropriate TME values were determined. For ostriches these amounted to 9.31 MJ/kg for lucerne and 14.47 MJ/kg for SBOCM. Markedly reduced TME value of 9.44 MJ/kg was observed for SBOCM in roosters while TME for maize was estimated at 14.60 MJ/kg. As roosters receiving the maize basal diet were in N-balance (Table 2 and Table 3), TME_n for maize remained at 14.60 MJ/kg, while TME_n of SBOCM was computed as 9.04 MJ/kg. Applying the correction for RN in ostriches yielded TME_n estimates of 8.84 MJ/kg and 13.44 MJ/kg for lucerne and SBOCM respectively.

3. *AME_n values of SFOCM determined directly*

Substantially reduced levels of intake (average 1098 g/bird/day) were observed for ostriches on the SFOCM diet apposed to intakes reported for Experiment 1. Roosters however experienced no difficulty in consuming the 1000 g/kg SFOCM diet and their average intake compared favourably to those reported for Experiment 1.

Significantly improved DMD of 0.604 was measured for ostriches vs. 0.376 for roosters. The congruent AME values were determined as 12.04 MJ/kg and 8.80 MJ/kg for ostriches and roosters respectively (Table 5). By applying corrections for RN, these values were reduced to 10.52 MJ/kg and 8.30 MJ/kg

for ostriches and roosters respectively, to yield estimates for AME_n.

4. *TME_n values of SFOCM determined by regression method*

The regressions for Experiment 2 are presented in Table 4. All slopes were significant and measurements were proportionally distributed along the linear models. As for Experiment 1, no estimate for EEL could be obtained as intercepts were not statistically significant ($p>0.05$).

DMD values of 0.638 and 0.384 (Table 6) estimated by regression for ostriches and roosters were in good agreement to the direct measurements reported in Table 5. Using the complement of the slopes for the energy balance relationships, TME values of 12.34 MJ/kg and 9.20 MJ/kg were computed for ostriches and roosters. Substantially higher levels of RN were measured in ostriches and a TME_n value of 10.79 MJ/kg was determined. The corresponding TME_n value for roosters was estimated at 8.89 MJ/kg. Although the TME and TME_n values of SFOCM for roosters were higher than estimates for AME and AME_n, were these differences not significant.

In both Experiment 1 and Experiment 2, significantly enhanced estimates were measured between ostriches and roosters with respect to DMD, AME, AME_n, TME and TME_n values.

DISCUSSION

The improved AME_n and TME_n values of SBOCM and SFOCM for ostriches vs. results obtained for roosters confirmed the previous findings and suggestions of Cilliers **et al.**,(1994a; 1994b; 1994c) that complete evaluation of all dietary constituents are required. Cilliers **et al.**, (1994a; 1994b; 1994c) showed markedly improved TME_n values for lucerne, maize, barley, triticale, oats and wheat bran as apposed to results obtained for roosters, indicating the unique digestibility features of ostriches.

The TME_n estimate of 8.84 MJ/kg for lucerne in the present study, is in good agreement to results reported by Cilliers **et al.**, (1994a; 1994b; 1994c). AME_n value of SFOCM viz. 8.30 MJ/kg for roosters in the present study, compares favourably to reported values by Evans (1985), Gous and Dennisson (1983) and Hayes and Du Preez (1994). Similarly AME_n of 9.20 MJ/kg is in agreement to the findings of Allen (1992) and Hayes **et al.**, (1994).

The cause of the significantly higher AME_n value of 14.54 MJ/kg vs. the TME_n value of 13.44 MJ/kg for SBOCM in ostriches is not clear. This discrepancy and higher error (variation) observed for SBOCM, questioned the accuracy of averaging direct measurements. The good fit (R^2) and lower standard error of estimating TME_n according to a multiple regression method in which the individual metabolisabilities

of 36 birds were pooled, seemed a more reliable estimate.

The substantially improved TME_n values of SBOCM and SFOCM viz. 13.44 MJ/kg and 10.79 MJ/kg indicated that the hulls in these oilcakes were utilised, hence enhancing the energy content of these ingredients. This was expected as Swart, Mackie and Hayes (1993) observed the production of fatty acids in the hind gut of ostriches, due to the digestion of cellulose and hemicellulose.

With knowledge of the energy values of SFOCM and SBOCM for ostriches, the utilisation of energy sources in diets for ostriches could markedly be reduced due to the substantial energy contribution from plant protein sources to the diet. This would enable the inclusion of higher levels of more available and inexpensive ingredients like lucerne hay in diets for ostriches. The more concentrated dietary sources could therefore be used in diets for poultry and swine, that will ensure enhanced economical utilisation of limit sources in the feed industry.

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TABLE 1: DIETARY CHARACTERISTICS AND RESULTS OF BALANCE STUDIES WITH SOYBEAN OILCAKE MEAL FED TO ROOSTERS AND OSTRICHES

OSTRICHES Experiment 1	Diet 1 Lucerne Basal 1000 g/kg	Diet 2 400 g/kg SBOCM 600 g/kg lucerne	Diet 3 600 g/kg SBOCM 400 g/kg lucerne
Protein, g/kg	175.27	288.70	337.10
Feed intake, kg/bird/day	1.559 ± 0.142	1.614 ± 0.133	1.387 ± 0.0853
DMD	0.501 ± 0.0120^{a}	0.588 ± 0.0107^{b}	0.654 ± 0.00757^{c}
AME MJ/kg	9.69 ± 0.257^{a}	12.46 ± 0.140^{b}	13.29 ± 0.122^{c}
RN, g/bird/day	23 ± 2.95^{a}	32 ± 3.06^{b}	34 ± 2.71^{c}
AME_n, MJ/kg	9.16 ± 0.277^{a}	11.73 ± 0.109^{b}	12.39 ± 0.112^{c}
ROOSTERS	Diet 1 Maize Basal 1000 g/kg	Diet 2 300 g/kg SBOCM 700 g/kg Lucerne	Diet 3 600 g/kg SBOCM 400 g/kg Lucerne
Protein, g/kg	84.08	182.75	289.26
Feed intake, g/bird/day	90 ± 5.79	89 ± 6.93	95 ± 8.35
DMD	0.836 ± 0.0122^{a}	0.689 ± 0.00643^{b}	0.570 ± 0.0180^{c}
AME, MJ/kg	14.51 ± 0.205^{a}	12.96 ± 0.123^{b}	11.43 ± 0.262^{c}
RN, g/bird/day	0.338 ± 0.202	0.254 ± 0.0753	0.446 ± 0.169
AME_n, MJ/kg	14.37 ± 0.184^{a}	12.86 ± 0.113^{b}	11.27 ± 0.216^{c}

SBOCM = Soybean oilcake meal

Estimates within the same row with common superscripts do not differ significantly ($p > 0.05$)

TABLE 2: THE INDIGESTIBLE, UNMETABOLISABLE AND UNRETAINABLE N PROPORTIONS OF SOYBEAN OILCAKE (SBOCM) FOR ROOSTERS AND OSTRICHES AS DETERMINED BY REGRESSION

OSTRICHES: Experiment 1	Digestibility	Energy Balance	N-Retention
Intercept	-18 ± 38*	-0.5 ± 0.693*	-2.7 ± 5.38*
Slope b_1 for lucerne	0.510 ± 0.0244	0.465 ± 0.0250	0.538 ± 0.121
Slope b_2 for SBOCM	0.274 ± 0.0316	0.214 ± 0.0288	0.608 ± 0.0613
R^2	0.960	0.949	0.838
ROOSTERS Experiment 1			
Intercept	1.1 ± 2.92*	7.6 ± 46*	0.532 ± 0.244
Slope b_1 for maize	0.154 ± 0.334	0.152 ± 0.0310	0.312 ± 0.208*
Slope b_2 for SBOCM	0.607 ± 0.0341	0.487 ± 0.0299	0.846 ± 0.0416
R^2	0.951	0.940	0.971

* Estimates marked ' * ' do not differ from zero ($p > 0.05$)

TABLE 3: DMD, RN, AME TME AME$_n$ and TME$_n$ VALUES OF SOYBEAN OILCAKE (SBOCM) FOR ROOSTERS AND OSTRICHES

	DMD	RN g/bird/day	AME MJ/kg	AME$_n$ MJ/kg
OSTRICHES				
a) Replacement Method				
Lucerne Basal	0.501 ± 0.0120	23 ± 2.95	9.69 ± 0.257	9.16 ± 0.277
SBOCM at 400 g/kg	0.718 ± 0.0322	45.5 ± 5.47	16.61 ± 0.271	15.58 ± 0.247
SBOCM at 600 g/kg	0.756 ± 0.0266	41 ± 4.93	15.69 ± 0.265	14.54 ± 0.262
b) Regression Method	DMD	RN g N/kg diet	TME MJ/kg	TME$_n$ MJ/kg
Lucerne	0.490 ± 0.00863	12.95 ± 1.20	9.31 ± 0.154	8.84 ± 0.198
SBOCM	0.726 ± 0.00790	28.1 ± 1.10	14.47 ± 0.133	13.44 ± 0.173
ROOSTERS				
a) Replacement Method	DMD	RN g/bird/day	AME MJ/kg	AME$_n$ MJ/kg
Maize basal	0.836 ± 0.0122	0.338 ± 0.0714	14.51 ± 0.205	14.37 ± 0.184
SBOCM at 300 g/kg	0.346 ± 0.0356	0.058 ± 0.0908	9.34 ± 0.397	9.33 ± 0.327
SBOCM at 600 g/kg	0.393 ± 0.0314	0.518 ± 0.0816	9.38 ± 0.209	9.20 ± 0.145
a) Regression Method	DMD	RN g N/kg diet	TME MJ/kg	TME$_n$ MJ/kg
Maize	0.846 ± 0.0118	0*	14.60 ± 0.189	14.60 ± 0.189
SBOCM	0.393 ± 0.00853	11.1 ± 0.747	9.44 ± 0.138	9.04 ± 0.165

* Birds were in N balance thus TME = TME$_n$

TABLE 4: THE INDIGESTIBLE, UNMETABOLISABLE AND UNRETAINABLE N PROPORTIONS OF SUNFLOWER OILCAKE MEAL, FOR OSTRICHES AND ROOSTERS AS DETERMINED BY REGRESSION

	Digestibility	Energy Balance	N-Retention
OSTRICHES			
Intercept	28 ± 47*	0.22 ± 0.688*	0.903 ± 8.19*
Slope	0.362 ± 0.0398	0.327 ± 0.0317	0.275 ± 0.118
R^2	0.912	0.930	0.402
ROOSTERS			
Intercept	1.7 ± 6.92*	50 ± 107*	-0.5 ± 0.406*
Slope	0.616 ± 0.0794	0.498 ± 0.0673	0.858 ± 0.0775
R^2	0.896	0.887	0.968

* Estimates marked ' * ' do not differ from zero ($p > 0.05$)

TABLE 5: DIETARY CHARACTERISTICS AND RESULTS OF BALANCE STUDIES WITH SUNFLOWER OILCAKE (SFOCM) FED TO OSTRICHES AND ROOSTERS

	Ostriches	Roosters
Protein g/kg	365.75	
Feed intake kg/bird/day	1.098 ± 0.154[a]	0.089 ± 0.486[b]
DMD	0.604 ± 0.0166[a]	0.376 ± 0.00865[b]
AME, MJ/kg	12.04 ± 0.236[a]	8.80 ± 0.111[b]
RN, g/bird/day	46 ± 7.00[a]	1.27 ± 0.0843[b]
AME_n, MJ/kg	10.52 ± 0.213[a]	8.30 ± 0.0882[b]

TABLE 6: TME AND TME_n VALUES OF SUNFLOWER OILCAKE, FED TO OSTRICHES AND ROOSTERS AS DETERMINED BY REGRESSION METHOD

	Ostriches	Roosters
DMD	0.638 ± 0.0133[a]	0.384 ± 0.0281[b]
RN g N/kg Diet	42 ± 2.30[a]	8.31 ± 1.60[b]
TME, MJ/kg	12.34 ± 0.194[a]	9.20 ± 0.436[b]
TME_n, MJ/kg	10.79 ± 0.278[a]	8.89 ± 0.494[b]

Estimates in Table 2 and Table 3 within the same row with common supercripts do not differ ($p>0.05$)

CHAPTER 8

A COMPARATIVE STUDY BETWEEN LUCERNE HAY, *PHRAGMITES AUSTRALIS* AND *ATRIPLEX NUMMULARIA* WITH RESPECT TO AME_n AND TME_n CONTENTS FOR MATURE OSTRICHES AND ROOSTERS

BY

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ABSTRACT

Phragmites australis (common reed) and *Atriplex nummularia* (saltbush) are readily available in the arid ostrich raising areas of South Africa. The aim of this study was to evaluate the potential of these ingredients as alternative sources of roughage in diets for ostriches. A comparative study between lucerne hay, common reed hay and saltbush hay with respect to their apparent and true metabolisable energy contents, corrected for nitrogen retention viz. AME_n and TME_n, were conducted with 36 mature ostrich males. These findings were also compared to AME_n and TME_n values obtained for mature roosters.

Lucerne, saltbush and common reed were used as such (1000 g/kg) to compile the three test diets for ostriches. In roosters, maize was used as the basal ingredient to dilute common reed and saltbush. Both saltbush and common reed were included at two dietary levels viz. 300 g/kg and 600 g/kg, to compile the various test diets for roosters. Results of lucerne for roosters were taken from Cilliers, Hayes, Maritz, Chwalibog & Du Preez (1994a).

AME_n values in ostriches were 7.07 ± 0.115 MJ/kg, 8.32 ± 0.244 MJ/kg and 9.16 ± 0.277 MJ/kg for saltbush, common reed and lucerne respectively. AME_n values differed significantly between these ingredients, but similar TME_n values were calculated by regression method for common reed and lucerne viz. 8.69 ± 0.337 MJ/kg and 8.99 ± 0.410 MJ/kg. Markedly reduced value of 7.09 ± 0.238 MJ/kg was however estimated for saltbush.

Substantially reduced AME_n and TME_n values were measured for roosters. The AME_n value for maize viz. 14.27 ± 0.183 MJ/kg was used to derive AME_n values for common reed and saltbush at the 300

g/kg and 600 g/kg levels of substitution. These values amounted to 3.13 ± 0.700 MJ/kg and 2.69 ± 0.361 MJ/kg for saltbush and 2.80 ± 0.583 MJ/kg and 2.79 ± 0.245 MJ/kg for common reed. These values were substantially lower that the AME_n values of 4.05 ± 0.321 MJ/kg and 4.49 ± 0.506 MJ/kg reported by Cilliers **et al.**, 1994a for lucerne. Similar TME_n values viz. 4.5 ± 0.271 MJ/kg and 4.03 ± 0.118 MJ/kg were calculated for lucerne and saltbush, but a significantly reduced estimate of 2.79 ± 0.147 MJ/kg was computed for common reed.

According to the energy contents of common reed and saltbush, it was concluded that these ingredients could be utilised as supplementary sources of roughage in diets for ostriches.

INTRODUCTION

Consistent periods of drought are often encountered in South Africa, resulting in deficiencies in the quantities of available sources of roughage. Due to the bulky nature of roughage and its low energy contents, cause that the purchase of these ingredients markedly increased dietary costs. Substantial levels of roughage, especially lucerne, are used in diets for ostriches due to their fibre digestible capabilities (Cilliers, Hayes, Maritz, Chwalibog & Du Preez, 1994a; Cilliers, Hayes, Chwalibog & Du Preez, 1994b).

In the arid areas of South Africa, a number of underutilised natural potential sources of roughage like *Phragmites australis* (common reed) are available. Common reed are often used as a stabiliser in the conservation of soil and the utilisation of this material are essential for effective conservation (Swiegers, 1985).

A number of studies with drought resistant fodders were conducted in South Africa and it was concluded that *Atriplex nummularia* (saltbush) can play a vital role as a roughage source in diets for sheep (Weston, Hogan & Hemsley, 1970; Jacobs, 1987; Hoon & King, 1992).

Due to the demand for roughage sources in diets for ostriches and the limit quantities in the typical arid ostrich raising areas, necessitate the determination of the energy contents of readily available alternative sources of roughage viz. saltbush and common reed.

This paper therefore deals with a comparative study between lucerne, *Phragmites australis* and *Atriplex nummularia* with respect to their TME_n and AME_n contents for mature ostriches. These results were also compared to values obtained for roosters.

MATERIAL AND METHODS

Diets and Treatments

Saltbush was pruned approximately 3 months prior to the study to allow young growth. The latter were cut and allowed to dry. Common reed in the bud stage just before bloom, were harvest on a local river bank. The dry saltbush, common reed and locally produced lucerne hay were then hammermilled through a 5 mm sieve and cold pelleted to minimise wastage.

Ostriches

Lucerne, saltbush and common reed were used as such to compile the various test diets for ostriches. The three test diets were allotted at random among 36 mature ostrich males weighing between 120 and 140 kg.

Group 1 received saltbush as a test diet (1000 g/kg)
Group 2 received lucerne as a test diet (1000 g/kg)
Group 3 received common reed as a test diet (1000 g/kg)

Roosters

The same samples of saltbush and common reed as used for ostriches were used to comprise test diets for roosters. Results on the energy contents of lucerne for roosters were taken from Cilliers **et al.,** (1994a) and are referred to as Experiment 3. Yellow maize meal were used as a basal ingredient to dilute saltbush and common reed to compile the various test diets in Experiment 1 and Experiment 2. In each experiment the test diets were distributed at random between a group of 30 adult roosters from the Lohmann Brown laying strain.

The various combinations were:

Experiment 1:
Group 1 received maize as a basal diet (1000 g/kg)
Group 2 received 700 g maize + 300 g saltbush per kg diet
Group 3 received 400 g maize + 600 g saltbush per kg diet

Experiment 2:

Group 1 received 700 g maize + 300 g common reed per kg diet

Group 2 received 400 g maize + 600 g common reed per kg diet

The same sample of maize used as basal diet in Experiment 1, were used to compile the two test diets in Experiment 2. Results from Experiment 1 for maize was used for the calculation of the metabolisabilities of common reed in Experiment 2.

Experiment 3:

The various test diets where lucerne was evaluated as the test ingredient in the study by Cilliers **et al.,** (1994a), were the following:

Group 1 received maize as a basal diet (1000 g/kg)

Group 2 received 750 g maize + 250 g lucerne per kg diet

Group 3 received 500 g maize + 500 g lucerne per kg diet

Animal Husbandry and Experimental Procedures

Ostriches

The same procedure for metabolisable energy determinations with ostriches as described by Cilliers **et al., (**1994a; 1994b) were applied in the present study. Results were obtained by means of total excreta collection with harnesses in metabolism cages. An adaption period of 14 days were applied to allow birds to adjust to the experimental diets. This was followed by a 5 day collection period in which feed consumption were accurately measured. Test diets were daily supplied at three levels of intake viz. 1200 g, 1600 g and 2000 g to enable an extended range of energy intakes for regression analises.

Roosters

For the evaluation of the test diets in roosters the DSQ-method of Du Preez, Duckitt & Paulse (1986) were used. Birds were initially starved for 20 hours and then offered the test diets for 4 days. The first 24 hours served as an adaption period, while feed intake and excreta output were collected for the successive 3 days. Daily levels of intake were restricted at 80 g, 110 g and 140 g/bird.

Analytical Procedures

Daily excretions were kept separate and stored at - 10 °C until the termination of trials. Dry daily voidings of excreta were proportionally pooled over days for individual birds and used for analises after fine grounding. Samples were analised for gross energy, using a solid state bomb calorimeter (Model CP 500, Digital Data Systems, P.O. Box 35872, Northcliff, Johannesburg), and for nitrogen by applying the macro-Kjeldahl method.

Calculations and Statistical Procedures

In ostriches where test diets were used as such to compile the various test diets, apparent metabolisable energy (AME) values were derived directly from results. The true metabolisable energy (TME) contents of these ingredients were determined by regression method as described by Cilliers **et al.,** (1994a; 1994b).

In roosters where maize was used to dilute saltbush and common reed to establish the various test diets, AME values for the test ingredients were calculated by the replacement method (Cilliers **et al.,** 1994a). TME values for the test ingredients were determined by multiple regression method (Cilliers **et al.,** (1994a; 1994b).

For the correction of AME and TME to N-corrected AME and TME (AME_n & TME_n), the factor of 36.5 kJ were used per kg retained N (RN). The two methods of applying corrections for RN to obtain AME_n and TME_n, were described by Cilliers **et al.,** (1994b).

RESULTS

Direct and Replacement method

Dietary and digestible characteristics viz. dry matter digestibility (DMD), AME and AME_n of the various test diets fed to ostriches and roosters are given in Table 1.

Saltbush were readily consumed by ostriches and similar consumption figures were measured for saltbush as for lucerne.

Markedly reduced levels of intake were however observed with birds receiving the common reed diet. Similar DMD values of 0.450 and 0.433 were determined for saltbush and common reed, but significantly improved mean DMD values of 0.501 was calculated for lucerne. AME values of 7.51 MJ/kg, 9.69 MJ/kg

and 8.59 MJ/kg were measured for saltbush, lucerne hay and common reed respectively (Table 3). These values were altered to 7.07 MJ/kg, 9.16 MJ/kg and 8.32 MJ/kg (AME_n) when applying the correction for the energy equivalent of RN. Differences between these ingredients were significant.

Substantially reduced levels of feed intake were observed in roosters for the saltbush test diets as dietary levels increased. Roosters however suffered no difficulty in consuming the common reed test diets. Similar to the findings for lucerne in Experiment 3 (results from Cilliers **et al.**, 1994a), markedly reduced DMD values were calculated for test diets as dietary levels of common reed and saltbush were increased. Using the mean DMD value of maize viz. 0.836, DMD values of saltbush and common reed were accordingly calculated as 0.303 and 0.139 at the 300 g/kg level of substitution and as 0.146 and 0.166 at the 600 g/kg level of substitution (Table 3)

The AME_n content of maize was estimated at 14.51 MJ/kg and AME values for saltbush and common reed amounted to 3.61 MJ/kg and 2.82 MJ/kg respectively at the 300 g/kg level of substitution (Table 3). The congruent values at the 600 g/kg levels were 2.20 MJ/kg and 2.83 MJ/kg. The mean AME_n value for maize was computed as 14.37 MJ/kg and AME_n values of 3.13 MJ/kg, 2.69 MJ/kg, 2.80 MJ/kg and 2.79 MJ/kg were calculated for saltbush and common reed at the two dietary levels of substitition. The AME_n content of 14.49 MJ/kg for maize reported in Experiment 3 compared favourably to the estimate for maize derived in Experiment 1. AME_n values for lucerne were 4.49 MJ/kg and 4.05 MJ/kg at the 250 g/kg and the 500 g/kg levels.

Regression method

Linear and multiple regressions representing digestibility, energy balance and N-retention are given in Table 2.

In ostriches, all slopes were significant with the exception of the model representing RN of birds receiving the saltbush diet, indicating that these birds were in N-equilibrium. Slope b_2 in the multiple regression model representing RN from saltbush in roosters, were also found not be different from zero ($p<0.05$).

Using the complement of the various slopes, yielded estimates for DMD, TME, RN and TME_n (Table 3). Significantly improved DMD values of 0.489 and 0.521 were calculated for common reed and lucerne in ostriches as opposed to 0.427 observed for saltbush. The TME content of common reed (8.98 MJ/kg)

compared favourably to the 9.62 MJ/kg estimated for lucerne. Both these estimates were however significantly higher than the TME value of 7.09 MJ/kg observed for saltbush. TME_n values of common reed and lucerne amounted to 8.67 MJ/kg and 8.99 MJ/kg respectively, while TME_n for saltbush remained at 7.09 MJ/kg as birds were in N-equilibrium.

DMD of maize in roosters were calculated as 0.864 and digestibility figures for saltbush and common reed were 0.321 and 0.186. These values are in agreement to the findings of Cilliers **et al.,** (1994a) reported in Experiment 3, where values of 0.823 and 0.108 were found for maize and lucerne respectively.

TME values amounted to 14.63 MJ/kg, 4.5 MJ/kg and 3.0 MJ/kg for maize, saltbush and common reed respectively, while values of 14.76 MJ/kg and 4.26 MJ/kg were observed for maize and lucerne in Experiment 3. Applying the correction for RN, yielded TME_n values of 14.37 MJ/kg, 4.50 MJ/kg, 2.79 MJ/kg for maize, saltbush and common reed respectively. The corresponding values for lucerne and maize in Experiment 3 were 4.03 MJ/kg and 14.47 MJ/kg. In contrast to the findings of improved mean AME_n values for lucerne as apposed to that of common reed and saltbush, similar TME_n values were calculated for lucerne and saltbush. Both these estimates were significantly different from the TME_n estimate for common reed.

DISCUSSION

Green feedstuffs were formerly common constituents of poultry diets, but its used has declined as it became non economical sources of nutrients. However for the aim of the present study where lucerne was compared to saltbush and common reed, it was interesting to note how the TME_n contents of these ingredients will compare.

Jonsson and McNab (1983) mentioned that the unpalatibility of diets containing fibrous ingredients could probably explain the findings that the AME content of fibrous ingredients differed as dietary levels are altered. Sibbald (1975) however explained these finding due to artefacts introduced from low feed consumptions.

The evaluation of saltbush, commmon reed and lucerne in roosters clearly demonstrated the inability of poultry to utilised fibrous ingredients. AME_n values for common reed were consistent between the two levels of substitution, but more variation were observed for saltbush, probably caused by the low

feed intakes. The reduced feed intakes observed for the saltbush test diets could be explained by its high sodiumchloride content of 3.5 % (Hoon **et al.,** 1992). The low feed intakes of the saltbush test diets could also explain the substantially higher TME_n value of 4.5 MJ/kg vs. 2.69 MJ/kg reported for the AME_n content of saltbush.

The reduced feed intake observed for ostriches consuming the common reed diet vs. the lucerne and saltbush diets, are in agreement to the findings of Swiegers (1985) who observed a similar tendency among sheep. The reduced levels of intake could probably be explained by the high cutin content of 3.5 % (Swiegers, 1985) that influenced the palatability of common reed. In contrast to the findings with roosters, ostriches experienced no obvious strain from the high sodiumchloride content in saltbush and were it readily consumed.

DMD of 0.450 and 0.427 measured for saltbush in ostriches are markedly lower than reported values of 0.584 for sheep (Hoon **et al.,** (1992). The question however exist if the state of growth from which the saltbush hay was made, was comparable to the samples tested in the present study.

With AME_n and TME_n values of 7.07 MJ/kg 7.09 MJ/kg for saltbush and 8.98 MJ/kg and 8.67 MJ/kg for common reed, these ingredients were inferior to lucerne (9.16 MJ/kg and 8.99 MJ/kg), but could still be utilised for supplementing roughage sources in diets for ostriches.

Considering the high cost of lucerne, both common reed and saltbush will compare favourably with lucerne as the only costs of the latter are in the harvesting. Further studies are now required to evaluate the tolerance levels of common reed and saltbush in diets for ostriches, without restraining growth. If results proof that these ingredients could be used in substantial levels, hence reducing dietary costs, it may even be a viable proposition for farmers to plant these ingredients.

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TABLE 1: DIETARY AND DIGESTIBLE CHARACTERISTICS OF TEST DIETS FED TO ROOSTERS AND OSTRICHES

OSTRICHES	1000 g/kg Saltbush	1000 g/kg Lucerne	1000 g/kg Common Reed
Protein, g/kg	118.23	175.27	104.50
Feed intake, kg/bird/day	1.533 ± 0.122	1.559 ± 0.142	1.277 ± 0.0965
DMD	0.450 ± 0.00816	0.501 ± 0.0121	0.443 ± 0.0107
AME MJ/kg	7.51 ± 0.108	9.69 ± 0.257	8.59 ± 0.250
RN, g/bird/day	18.72 ± 2.00	23.00 ± 2.95	9.77 ± 1.01
AME_n, MJ/kg	7.07 ± 0.115	9.16 ± 0.277	8.32 ± 0.244
ROOSTERS EXPERIMENT 1	**DIET 1: Maize basal**	**DIET 2: 300 g/kg Saltbush 700 g/kg Maize**	**DIET 3: 600 g/kg Saltbush 400 g/kg Maize**
Protein, g/kg	84.10	93.94	102.25
Feed intake, g/bird/day	90 ± 5.76	68.1 ± 2.98	26 ± 4.46
DMD	0.836 ± 0.0122	0.676 ± 0.0139	0.422 ± 0.0299
AME, MJ/kg	14.51 ± 0.205	11.24 ± 0.225	7.11 ± 0.454
RN, g/bird/day	0.338 ± 0.0714	0.463 ± 0.057	-0.07 ± 0.0865
AME_n, MJ/kg	14.37 ± 0.183	11.00 ± 0.216	7.36 ± 0.353
EXPERIMENT 2	**DIET 1 Maize basal**	**DIET 2 700 g/kg Maize 300 g/kg Reed**	**DIET 3 400 g/kg Maize 600 g/kg Reed**
Protein, g/kg	84.10	85.90	89.54
Feed intake, g/bird/day	90 ± 5.76	75 ± 3.73	89 ± 4.53
DMD	0.836 ± 0.0122	0.627 ± 0.0843	0.434 ± 0.00593
AME, M/kg	14.508 ± 0.205	11.00 ± 0.116	7.50 ± 0.119
RN, (g/bird/day)	0.338 ± 0.0714	0.225 ± 0.0277	0.225 ± 0.0559
AME_n, MJ/kg	14.37 ± 0.183	10.90 ± 0.119	7.42 ± 0.139
EXPERIMENT 3[a]	**DIET 1 Maize basal**	**DIET 2 750 g/kg Maize 250 g/kg Lucerne**	**DIET 3 500 g/kg Maize 500 g/kg Lucerne**
Protein, g/kg	87	113	138
Feed intake, g/bird/day	87 ± 3.00	77 ± 6.16	68 ± 5.90
DMD	0.828 ± 0.0025	0.639 ± 0.0051	0.473 ± 0.0053
AME, MJ/kg	14.62 ± 0.0363	12.23 ± 0.0847	9.53 ± 0.0963
RN, g/bird/day	0.320 ± 0.0235	0.51 ± 0.0646	0.48 ± 0.113
AME_n, MJ/kg	14.49 ± 0.0460	11.85 ± 0.115	9.28 ± 0.156

[a] Results from Cilliers et al., 1994a

TABLE 2: THE INDIGESTIBLE, UNMETABOLISABLE AND UNRETAINABLE N PROPORTIONS OF SALTBUSH, LUCERNE AND COMMON REED FOR ROOSTERS AND OSTRICHES AS DETERMINED BY REGRESSION METHOD

	Digestibility	Energy Balance	N-Retention
OSTRICHES			
Saltbush			
Intercept	1.29 ± 30.8*	-0.62 ± 0.460*	5.0 ± 1.94*
Slope	0.573 ± 0.0392	0.554 ± 0.0367	0.182 ± 0.131*
R^2	0.977	0.979	0.280
Lucerne			
Intercept	28 ± 78*	-0.1 ± 1.61	3.9 ± 6.99
Slope	0.479 ± 0.0487	0.447 ± 0.0575	0.384 ± 0.115
R^2	0.933	0.896	0.470
Common Reed			
Intercept	72 ± 48*	0.47 ± 1.37*	0.99 ± 2.63
Slope	0.511 ± 0.0370	0.464 ± 0.0623	0.496 ± 0.120
R^2	0.950	0.848	0.632
ROOSTERS			
Saltbush			
Intercept	3 ± 1.68*	32 ± 27.5*	0.534 ± 0.0924
Slope b_1 for maize	0.129 ± 0.0193	0.135 ± 0.0183	0.274 ± 0.0790
Slope b_2 for saltbush	0.679 ± 0.0656	0.717 ± 0.0703	-0.325 ± 0.195*
R^2	0.817	0.815	0.591
Common Reed			
Intercept	2.4 ± 2.44*	8.1 ± 40*	0.294 ± 0.127
Slope b_1 for maize	0.136 ± 0.0290	0.150 ± 0.0279	0.467 ± 0.112
Slope b_2 for reed	0.814 ± 0.0320	0.821 ± 0.0331	0.649 ± 0.112
R^2	0.982	0.980	0.579
Lucerne[a]			
Intercept	0.02 ± 0.015*	-0.03 ± 0.0464*	0.34 ± 0.113
Slope b_1 for maize	0.177 ± 0.104	0.158 ± 0.0103	0.440 ± 0.0948
Slope b_2 for lucerne	0.892 ± 0.0173	0.754 ± 0.0166	0.411 ± 0.0715
R^2	0.993	0.991	0.525

[a] Results from Cilliers et al., 1994a

TABLE 3: DMD, RN, AME, TME, AME_n AND TME_n OF SALTBUSH, LUCERNE AND COMMON REED FOR ROOSTERS AND OSTRICHES

	DMD	RN g/bird/day	AME MJ/kg	AME_n MJ/kg
OSTRICHES				
a) Direct method				
Saltbush	0.450 ± 0.00816	18.72 ± 2.00	7.51 ± 0.108	7.07 ± 0.115
Lucerne	0.501^{A} ± 0.0121	23.00 ± 2.95^{A}	9.69 ± 0.257^{A}	9.16 ± 0.277^{A}
Common Reed	0.433 ± 0.0107	9.77 ± 1.01^{B}	8.59 ± 0.250^{B}	8.32 ± 0.244^{B}
b) Regression Method	**DMD**	**RN g N/kg FEED**	**TME MJ/kg**	**TME_n MJ/kg**
Saltbush	0.427^{A} ± 0.0160	0*	7.09 ± 0.238	7.09 ± 0.238
Lucerne	0.521 ± 0.0172	17.28 ± 1.54	9.62 ± 0.354^{A}	8.99 ± 0.410^{A}
Common Reed	0.489 ± 0.011	8.43 ± 0.605^{A}	8.98 ± 0.315^{A}	8.67 ± 0.337^{A}
ROOSTERS				
a) Replacement Method	**DMD**	**RN g/bird/day**	**AME MJ/kg**	**AME_n MJ/kg**
Maize basal	0.836 ± 0.0122^{A}	0.338 ± 0.0714^{A}	14.51 ± 0.205^{A}	14.27 ± 0.183^{A}
Saltbush at 300 g/kg	0.303 ± 0.146^{BC}	0.755 ± 0.0639^{B}	3.61 ± 0.791^{BC}	3.13 ± 0.700^{BC}
Saltbush at 600 g/kg	0.146 ± 0.0505^{BC}	-0.342 ± 0.0231^{C}	2.20 ± 0.591^{C}	2.69 ± 0.361^{C}
Reed at 300 g/kg	0.139 ± 0.0400^{BC}	-0.039 ± 0.0362^{C}	2.82 ± 0.615^{C}	2.80 ± 0.583^{BC}
Reed at 600 g/kg	0.166 ± 0.0128^{B}	0.150 ± 0.0990^{C}	2.83 ± 0.241^{C}	2.79 ± 0.245^{C}
Maize basal[a]	0.828 ± 0.0025^{A}	0.320 ± 0.0234^{A}	14.62 ± 0.036^{A}	14.49 ± 0.046^{A}
Lucerne at 250 g/kg[a]	0.072 ± 0.0235^{C}	0.640 ± 0.302^{AB}	5.06 ± 0.376^{B}	4.49 ± 0.506^{B}
Lucerne at 500 g/kg[a]	0.118 ± 0.0112^{C}	1.080 ± 0.280^{B}	4.44 ± 0.200^{B}	4.05 ± 0.321^{B}
a) Regression Method	**DMD**	**RN g N/kg FEED**	**TME MJ/kg**	**TME_n MJ/kg**
Maize	0.864 ± 0.169	7.2 ± 0.533^{A}	14.63 ± 0.169^{A}	14.37 ± 0.189^{A}
Saltbush	0.321 ± 0.0159^{A}	0*	4.5 ± 0.271^{B}	4.50 ± 0.271^{B}
Common Reed	0.186 ± 0.00754^{B}	5.9 ± 0.441	3.00 ± 0.131	2.79 ± 0.147
Maize[a]	0.823 ± 0.0026	7.81 ± 0.330	14.76 ± 0.0452^{A}	14.47 ± 0.0573^{A}
Lucerne[a]	0.108 ± 0.00653^{C}	6.22 ± 1.25	4.26 ± 0.108^{B}	4.03 ± 0.118^{B}

[a] Results from Cilliers et al., 1994a

Estimates of test ingredients for the same parameter (column) and method, with common superscripts do not differ significantly ($p > 0.05$).

CHAPTER 9

SWEET WHITE *LUPINUS ALBUS (cv BUTTERCUP)* AS A POTENTIAL ENERGY SOURCE FOR OSTRICHES AND POULTRY

BY

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ABSTRACT

In an experiment involving 12 roosters and 24 mature ostrich males, the nitrogen corrected apparent and true metabolisable energy content (AME_n and TME_n) were determined by balance method for *Lupinus albus (cv Buttercup).* Lupins were used as such (1000 g/kg) for experimentation in roosters. In ostriches, lucerne hay was used as a basal diet (1000 g/kg) and given to 12 ostriches, while the second group of birds received a test diet consisting of 400 g/kg of lucerne and 600 g/kg of lupins. Feed intake and excreta collection with ostriches were carried out for 5 days after an initial adaption period of 7 days. In roosters, the duration of experimentation lasted for 72 hours after an initial period of starvation (20 hours), followed by an adaption period of 24 hours.

The high fibre content in lupins caused markedly reduced digestibilities for roosters, but ostriches experienced no difficulty in metabolising the cellulose content in lupins. Hence significantly ($p<0.05$) improved AME_n values were observed for ostriches viz. 15.91 MJ/kg as opposed to a mean estimate of 9.55 MJ/kg calculated for roosters. The mean AME_n value of lucerne was 9.16 MJ/kg.

TME_n values were determined by regression method and amounted to 8.64 MJ/kg and 14.61 MJ/kg in ostriches for lucerne and lupins respectively. A TME_n estimate of 9.40 MJ/kg was computed for lupins in roosters. The TME_n contents of lupins were superior to that of soybean and sunflower oilcake meal (Cilliers, Hayes, Chwalibog & Du Preez. 1994b), hence providing that dietary use of lupins will not restrain growth and production in ostriches, it could be a valuable and versatile protein and energy source in diets for ostriches.

INTRODUCTION

Increased interest is expressed in dietary use of sweet lupins in a wide range of animal feeding systems due to its favourable protein and energy contents (Grain Pool of Western Australia, 1991). The fibrous hull of lupins markedly reduce its energy content for poultry as apposed to ruminants, where lupins compare favourably to grains.

Various lupin varieties and cultivars exist with substantial differences in antri-nutritional factors such as alkaloid levels, anti-trypsins, haemagglutins (lectins), tannis, phytate and alkyl resorcinol (Cheeke and Kelly, 1988). The development of sweet cultivars with reduced levels of these anti-nutritional factors verify its evaluation to establish whether any nutritional disorders occur.

Results by Cilliers, Hayes, Chwalibog and Du Preez (1994a, 1994b), on the AME_n and TME_n contents of barley, triticale, oats, soybean oilcake meal and sunflower oilcake meal for ostriches, indicated that the fibrous content in these ingredients and the non-starch polysaccharides in the grains, caused no limitation on its metabolisability, as were observed for roosters. Due to these enhanced energy contents for ingredients in ostriches, raises the question to what extent lupins would be suitable as an energy source in diets for ostriches.

This paper therefore deals with an comparative study between mature ostriches and roosters with respect to the AME_n and TME_n contents of sweet lupins (*L. albus, cv Buttercup*).

MATERIAL AND METHODS

Diets and Treatments

Locally produced lucerne hay was used as a basal ingredient to dilute lupins for ostriches. Lupins and the lucerne were hammermilled through a 5 mm sieve and test diets were cold pelleted to minimise wastage.

Ostriches

Two diets were compiled and allotted at random among 24 mature ostrich males weighing between 120 and 140 kg. The diets were the following:

Group 1 received only lucerne as a basal diet (1000 g/kg)
Group 2 received 400 g lucerne + 600 g lupins per kg diet

Roosters

The same samples of lupins used for ostriches, were fed as such to roosters. The lupin diet (1000 g/kg) was distributed at random between 12 mature roosters from the Lohmann Brown laying strain.

Animal Husbandry and Experimental Procedures

Ostriches

The same procedure for metabolisable energy determinations with ostriches as described by Cilliers **et al.,** (1994a; 1994b; 1994c) were applied in the present study. Results for the balance method were obtained by means of total excreta collection with harnesses in metabolism cages. An initial adaption period of 7 days were allowed for adjustment of birds to the experimental diets. Excreta and feed consumption were then accurately measured for the following 5 days. Test diets were daily supplied at three levels of intake viz. 1300 g, 1700 g and 2100 g to enable an extended range of energy intakes for regression analises.

Roosters

Lupins in roosters were evaluated according to the DSQ-method of Du Preez, Duckitt & Paulse (1986). Birds were initially starved for 20 hours followed by an 24 hour adaption period to the experimental diet. Feed intake and excreta output were then accurately measured for the successive 3 days. Daily levels of intake were restricted at 80 g, 110 g and 140 g/bird.

Analytical Procedures

Daily excretions were kept separate and stored at - 10 °C until the termination of trials. Dry daily voidings of excreta were proportionally pooled over days for individual birds and used for analises after fine grounding. Samples were analised for gross energy, using a solid state bomb calorimeter (Model

CP 500, Digital Data Systems, P.O. Box 35872, Northcliff, Johannesburg). Nitrogen analysis were done by means of the standard macro-Kjeldahl method.

Calculations and Statistical Procedures

Only one test diet together with a basal diet were used for the evaluation of lupins in ostriches. The apparent metabolisable energy (AME) value of lucerne (basal diet) were used to derive the AME content of lupins in the test diet. The procedure is called the replacement method and was explained by Cilliers **et al.**, (1994c). In roosters where lupins were used as such, estimates were calculated directly.

The true metabolisable energy (TME) content of lupins were computed by regression method as described by Cilliers **et al.,** (1994a; 1994b; 1994c). In ostriches where lupins were substituted by 400 g/kg of lucerne, an multiple regression model were applied where slope b_1 and slope b_2 estimated the unmetabolisable proportions of lucerne and lupins respectively. In roosters, a simple linear model was applied as lupins were used as such for the experimental diet for roosters.

For the correction of AME and TME to N-corrected AME and TME (AME_n & TME_n), the factor of 36.5 kJ were used per kg retained N (RN). The two methods of applying corrections for RN viz. directly and by regression to obtain AME_n and TME_n, were described by Cilliers **et al.,** (1994a).

RESULTS

Direct and Replacement method

Dietary and digestible characteristics viz. dry matter digestibility (DMD), AME and AME_n of experimental diets fed to ostriches and roosters are given in Table 1.

Similar mean feed consumption figures were observed for lucerne and the 600 g/kg lupin test diet. The substitution of lucerne by lupins markedly improved the DMD of lucerne (basal diet) viz. 0.501 to 0.667 for the test diet. From these results, the mean DMD estimate for lupins (1000 g/kg) was calculated that amounted to 0.778 (Table 3). Significantly reduced digestibilities were observed in roosters where a mean estimate of 0.356 was measured.

The AME content of lucerne for ostriches was determined as 9.69 MJ/kg and 14.10 MJ/kg for the test diet (Table 1). AME content for 1000 g/kg lupins were accordingly calculated as 17.04 MJ/kg (Table 3). By applying corrections for RN, AME_n values of 9.16 MJ/kg and 13.21 MJ/kg were observed for lucerne and the test diet respectively that yielded a mean estimate of 15.91 MJ/kg for lupins (Table 3). Significantly reduced AME_n values were measured in roosters viz. 9.55 MJ/kg.

All slopes representing the various parameters viz. indigestibility, unmetabolisability and unretainable N proportions, were significantly for ostriches (Table 2). For roosters however, the linear model representing RN was not significant, indicating that these birds were in N-equilibrium. All intercepts of significant models were found to be not statistically different from zero ($p>0.05$). Hence no estimate of endogenous contributions could be established.

The complement of the slopes for the digestibility models yielded DMD values of 0.478 and 0.767 for lucerne and lupins in ostriches and 0.338 for lupins in roosters (Table 3). TME values for lucerne and lupins in ostriches were 9.12 MJ/kg and 15.64 MJ/kg respectively. The congruent TME value for lupins in roosters was 9.40 MJ/kg.

Applying the correction for RN as estimated by the multiple regression model for ostriches altered TME values markedly and TME_n values of 14.61 MJ/kg and 8.64 MJ/kg were calculated for lupins and lucerne respectively. As roosters were in N equilibrium, TME_n for lupins remained at 9.40 MJ/kg as estimated for TME.

DISCUSSION

In South Africa where large amounts of protein sources are important to meet demand for protein, consistent evaluation of alternative sources are required to determine the possible cost effective utilisation of alternative sources in diets for monogastrics and ruminants. The quality of protein and especially the amino acid availability in these sources are the first priority when deciding on the merit of using an alternative source. For the economic evaluation and future role of an alternative proteineous ingredient, the energy contribution together with its amino acid content became the deciding factors in choosing such an ingredient in least cost diet formulation

Various scientific papers listed by Eckermans (1993), proof that lupins could make a substantial contribution and saving to diets for monogastric animals and even increased dietary levels are recommended for ruminants (Basson & Coetzee, 1993). Prinsloo, Smith & Rhode (1992) and Olver

(1987) evaluated *L. albus (cv Buttercup)*, in diets for layers and broilers and concluded that the inclusion of lupins up to 300 g/kg for layers and 400 g/kg for broilers had no significant deleterious effect on animal performance.

In the present study only the metabolisable energy contents of *L. albus (cv Buttercup)* were determined for ostriches and roosters. In contrast to the findings in roosters, the fibrous hull cause no detrimental effect on the digestibility and metabolisability of lupins in diets for ostriches. These findings are in agreement to previous results reported by Cilliers **et al.,** (1994a; 1994b; 1994c), that substantially improved metabolisabilities were observed for fibrous ingredients in ostriches as apposed to values determined for roosters. The average fibre content in lupin seed is 160 g/kg which is mainly compiled out of readily digestible cellulose (Grain Pool of Western Australia, 1991). Swart, Mackie and Hayes (1993) confirmed the digestibility of cellulose and hemi-cellulose by ostriches and concluded that the fibre digestible capabilities of ostriches could substantially contribute to the energy contents of ingredients fed to ostriches.

It roosters where lupins were fed as such, it seemed that the anti-nutritional factors like trypsin inhibitors became in excess causing that the protein in lupins could not be utilised. No N retention were therefore observed as evident from the findings reported in Table 2 and Table 3. As no correction for retained N was applied TME and AME might overestimate the TME_n and AME_n values of lupines when it is used at normal dietary levels of 300 g/kg as suggested by Prinsloo **et al.,** 1992. The TME_n and AME_n estimates of 9.40 MJ/kg and 9.55 MJ/kg are however in agreement to the findings Watkins, Manning, Al-Athari (1988) viz. 9.21 MJ/kg for *L. albus (cv. Ultra).*

The AME_n and TME_n values for lucerne viz. 9.16 MJ/kg and 8.64 MJ/kg are in agreement to previous findings for ostriches, reported by Cilliers **et al.,** (1994a; 1994b; 1994c). The TME_n value of 14.61 ± 0.340 MJ/kg for lupins in ostriches is significantly higher than congruent TME_n values reported for soybean oilcake and sunflower oilcake viz. 13.44 ± 0.173 MJ/kg and 10.79 ± 0.278 MJ/kg (Cilliers **et al.,** 1994b).

The enhance TME_n estimates for lupins in comparison to the oilcakes and some cereals, could probably be explained by its high fatty acid content. According to the Grain Pool of Western Australia (1991), constitute the fatty acid content approximately 70 g/kg of the total seed composition. Olver (1987) determined an oil content of 90 g/kg for *L. albus (cv Buttercup)*. Apart from the digestibility of the fibrous hull in lupins by ostriches, is it possible that ostriches are capable of utilising oil or fat to an higher degree than poultry. This could also contribute to the substantially enhance energy content of lupins for ostriches as apposed to that for roosters.

Results in the present study necessitate the further determination of the tolerance levels of lupins by ostriches without restricting growth, production and feed conversions. Although results in the present study were obtained with mature ostriches, should these results directly be applicable to younger birds. Cilliers **et al.,** (1994d) confirmed that similar TME_n values were determined for lucerne and barley in younger and mature ostriches. With a TME_n content of 14.61 MJ/kg, *L. Albus (cv. Buttercup)* compares favourably with the energy sources, maize and barley (Cilliers **et al.,** 1994a), and should lupins be a versatile ingredient, contributing substantial amounts of energy and protein in diets for ostriches.

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TABLE 1: DIETARY CHARACTERISTICS AND RESULTS OF BALANCE STUDIES FOR TEST DIETS FED TO ROOSTERS AND OSTRICHES

	Diet 1 1000 g/kg Lucern Basal	Diet 2 400 g/kg Lucerne 600 g/kg Lupins
Ostriches		
Protein, g/kg	175.27	287.80
Feed intake, kg/bird/day	1.601 ± 0.153	1.613 ± 0.0784
DMD	0.501 ± 0.0121	0.667 ± 0.00849
AME, MJ/kg	9.69 ± 0.257	14.10 ± 0.0914
RN, g/bird/day	23 ± 2.95	39 ± 3.13
AME_n, MJ/kg	9.16 ± 0.277	13.21 ± 0.0723
Roosters	1000 g/kg Lupins	
Protein, g/kg	356.08	
Feed intake g/bird/day	78 ± 3.40	
DMD	0.356 ± 0.0151	
AME, MJ/kg	9.46 ± 0.225	
RN, g/bird/day	-0.279 ± 0.0928	
AME_n, MJ/kg	9.55 ± 0.193	

For roosters, lupins were used as a complete diet, 1000 g/kg

TABLE 2: THE INDIGESTIBLE, UNMETABOLISABLE AND UNRETAINABLE N PROPORTIONS OF LUCERNE AND LUPINS FED TO ROOSTERS AND OSTRICHES, AS DETERMINED BY REGRESSION METHOD

Ostriches	Digestibility	Energy Balance	N-Retention
Intercept	-41 ± 63*	-0.9 ± 1.14*	-2 ± 8.79*
Slope b_1 for lucerne	0.522 ± 0.0398	0.476 ± 0.0415	0.530 ± 0.197
Slope b_2 for lupins	0.233 ± 0.0461	0.183 ± 0.0407	0.506 ± 0.111
R^2	0.947	0.931	0.611
Roosters			
Intercept	-1.4 ± 1.29*	-4.3 ± 146*	4.1 ± 0.371
Slope b_1 for lupins	0.662 ± 0.171	0.509 ± 0.0979	0.200 ± 0.0831*
R^2	0.714	0.794	0.689

* Estimates were not different from zero ($p > 0.05$)

TABLE 3: DMD, RN, AME, TME, AME_n AND TME_n VALUES OF LUPINS FOR ROOSTERS AND OSTRICHES

	DMD	RN g/bird/day	AME MJ/kg	AME_n MJ/kg
Ostriches				
a) Replacement Method				
Lucerne Basal	0.501 ± 0.0121	23 ± 2.95	9.69 ± 0.257	9.16 ± 0.277
Lupins	0.778 ± 0.0163	50 ± 5.57	17.04 ± 0.172	15.91 ± 0.221
b) Regression Method	DMD	RN g N/kg/diet	TME MJ/kg	TME_n MJ/kg
Lucerne Basal	0.478 ± 0.0141	13.18 ± 1.95	9.12 ± 0.255	8.64 ± 0.326
Lupins	0.767 ± 0.0154	28 ± 2.11	15.64 ± 0.260	14.61 ± 0.340
Roosters	DMD	RN g/bird/day	AME MJ/kg	AME_n MJ/kg
a) Direct Method				
Lupins	0.356 ± 0.0151	-0.279 ± 0.0928	9.46 ± 0.225	9.55 ± 0.193
b) Regression Method	DMD	RN g N/kg diet	TME MJ/kg	TME_n MJ/kg
Lupins	0.338 ± 0.0646	0	9.40 ± 0.662	9.40 ± 0.662

CHAPTER 10

A COMPARATIVE STUDY BETWEEN ROOSTERS AND MATURE OSTRICHES WITH RESPECT TO THE TRUE AND APPARENT METABOLISABLE ENERGY CONTENTS OF OSTRICH MEAT AND BONE MEAL AND FISH MEAL

BY

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ABSTRACT

Two experiments were conducted with ostriches and roosters two assess the AME_n and TME_n contents of fish meal (FM) and ostrich meat and bone meal (MBM). In ostriches, MBM and FM was diluted with lucerne hay to compile 2 dietary levels of test ingredient supplementation viz. 200 g/kg and 400 g/kg for MBM and 250 g/kg and 500 g/kg for FM. In roosters, maize was used to compile FM and MBM test diets where test ingredients comprised 150 g/kg and 300 g/kg of test diets (FM and MBM) were used. AME_n values for FM and MBM were calculated according to the replacement method, while TME_n values were derived from multiple regression analysis.

Significantly improved ($p<0.05$) AME_n values of 13.77 ± 1.03 MJ/kg and 13.05 ± 0.102 MJ/kg were calculated for MBM at the two dietary levels as opposed to values of 8.46 ± 0.493 MJ/kg and 7.93 ± 0.131 MJ/kg for roosters. Similarly for MBM, markedly improved AME_n values of 15.72 ± 1.27 MJ/kg and 15.80 ± 0.476 MJ/kg were observed for FM at the two dietary levels in ostriches in comparison to values of 11.52 ± 1.29 MJ/kg and 13.62 ± 0.381 MJ/kg for roosters. AME_n values for maize in roosters amounted to 14.46 ± 0.194 MJ/kg and 14.05 ± 0.0912 MJ/kg in Experiment 1 and Experiment 2 respectively. AME_n values of 9.57 ± 0.252 and 9.16 ± 0.262 MJ/kg were calculated for lucerne in ostriches in the two studies.

TME_n values yielded substantially reduced variation as was observed for AME_n values and were 12.81 ± 0.203 MJ/kg and 15.13 ± 0.315 MJ/kg for MBM and FM respectively in ostriches. The congruent TME_n values of lucerne in these studies were 9.67 ± 0.263 MJ/kg and 8.77 ± 0.351 MJ/kg respectively. Significantly reduced TME_n values were measured in roosters for both MBM and FM and amounted to 8.34 ± 0.126 MJ/kg and 13.95 ± 0.190 MJ/kg respectively.

Results in the present study suggest that both MBM and FM would make a substantial energy contribution to diets of ostriches. The improved metabolisable energy contents of FM and MBM in comparison to that obtained for roosters, are in agreement to previous findings of Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994a) and Cilliers, Hayes, Chwalibog and Du Preez (1994b; 1994c; 1994d; 1994e) for other ingredients. With TME_n estimates for most of the common ingredients used in diets of ostriches, results on the utilisation efficiency of these energy values are now required to establish requirement recommendations for ostriches.

INTRODUCTION

Ostriches have been raised for at least 80 years, but very little published research information about the nutrition of ostriches is available. Nutritionists extrapolated dietary recommendations for poultry in an attempt to supply the required nutritional quantities to ostriches. Increased interest in ostrich production emphasised that numerous raising and hatchability problems may be due to insufficient nutrition and warranted the determination of the nutritional values of various ingredients for ostriches.

Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994a) and Cilliers, Hayes, Chwalibog and Du Preez (1994b; 1994c; 1994d; 1994e) evaluated a number of ingredients viz. lucerne, barley, oats, triticale, maize, wheat bran, soybean oilcake meal, sunflower oilcake meal and lupins with ostriches and significant improved TME_n and AME_n values were derived for ostriches vs. that for poultry.

Ostrich meat and bone meal from the remains at ostrich abattoirs could make a substantial contribution to the dietary supply of ostriches due to its competitive cost in relation to that of fish meal. No information on the energy content of both these ingredients for ostriches could be found in literature and it was decided to compare the metabolisabilities of these ingredients in ostriches to that of roosters.

This paper deals with a comparative study between adult roosters and mature ostriches with respect to the true and apparent metabolisable energy content, corrected to N-equilibrium, of meat and bone meal (MBM) and fish meal (FM).

MATERIALS AND METHODS

Diets and Treatments

Two consecutive experiments were conducted with MBM and FM as test ingredients. In ostriches, lucerne hay was used to dilute MBM and FM, while yellow maize was used in roosters.

Ostriches

Three combinations of MBM and locally produced lucerne hay were used to compile test diets for energy evaluations in ostriches (Experiment 1):

Group 1: received lucerne as a basal diet (1000 g/kg)
Group 2: received test diet 1 consisting of 200 g/kg MBM and 800 g/kg lucerne
Group 3: received test diet 2 consisting of 400 g/kg MBM and 600 g/kg lucerne

Three test diets comprising of FM and lucerne hay were used in Experiment 2:

Group 1: received lucerne as a basal diet (1000 g/kg)
Group 2: received test diet 1 consisting of 250 g/kg FM and 750 g/kg lucerne
Group 3: received test diet 2 consisting of 500 g/kg FM and 500 g/kg lucerne

Lucerne hay were hammermilled through a 6 mm sieve and all diets were cold pelleted (8 mm) to minimise wastage.

Roosters

Three combinations of MBM and yellow maize were used in test diets for roosters in Experiment 1:

Group 1: received yellow maize as basal diet (1000 g/kg)
Group 2: received test diet 1 consisting of 150 g/kg MBM and 850 g/kg maize
Group 3: received test diet 2 consisting of 300 g/kg of MBM and 700 g/kg of maize.

Three FM test diets were offered to roosters in Experiment 2:

Group 1: received yellow maize as basal diet (1000 g/kg)
Group 2: received test diet 1 consisting of 150 g/kg FM and 850 g/kg maize
Group 3: received test diet 2 consisting of 300 g/kg of FM and 700 g/kg of maize.

Animal Husbandry

Ostriches

The technique described by Cilliers **et al.,** (1994a; 1994b) for metabolisable energy determinations with ostriches was used. Mature ostrich males (30 months of age) were used, weighing between 110 and 120 kg, and accustomed to the handling procedures and metabolism crates.

The test diets were offered to the birds for 7 days prior to experimentation. Birds were then fitted with excreta collection harnesses and individually placed in the metabolism crates, while feed intake and excreta collection were accurately measured for the following 5 days. Test diets were provided at daily intake levels of 1500, 2000 and 2500 g/bird to enable an extended range of energy intakes for regression analises.

Roosters

Test diets in Experiment 1 and Experiment 2 were evaluated according to the DSQ-method of Du Preez, Duckitt & Paulse (1986). The various test diets were allotted to 30 adult roosters (Lohmann Brown laying strain) for an adaption period of 24 hours, after they have been starved for 20 hours. Test diets were then offered for a period of 3 days in which daily intakes were restricted at 80, 110 and 140 g/bird. Feed consumption and excreta output were accurately measured over the latter 72 hour period.

Analytical Procedures

Daily excretions were kept separate and stored at - 10°C until the termination of trials. Excreta were dried in a forced draft oven at 80 °C to constant weight and allowed to equilibrate with atmospheric moisture for 24 hours. Dry daily voidings of individual birds were proportionally pooled after fine grounding and used for analysis. Gross energy (GE) was estimated by using a solid state bomb calorimeter (Model CP 500, Digital Data Systems, P.O. Box 35872, Northcliff, Johannesburg.) while nitrogen (N) analysis were determined by the macro-Kjeldahl procedure.

Calculation and statistical analysis of results

The AME and AME_n contents of FM and MBM were calculated according to the replacement method (Cilliers **et al.**, 1994a). For the correction of AME to AME_n, the factor of 36.5 kJ/g N retained (RN) were used.

TME values for FM and MBM were derived from regression analysis (Cilliers **et al.**, 1994a; 1994b) where a multiple regression ($Y = a + b_1X_1 + b_2X_2$) were used. X_1 represented the contribution from the basal ingredient (lucerne or maize) and X_2 represented the contribution from the test ingredient (MBM or FM). Regression equations were calculated for digestibility, energy balance and N retention (RN) and the complement of these slopes were then used for the calculation of dry matter digestibility (DMD), TME (MJ/kg) and N-retention (g N/kg diet). With an estimate for RN per kg of test ingredient consumed, TME was accordingly adjusted to TME_n. Results were calculated and evaluated using the GLM option of the SAS Institute (1985).

RESULTS

1. *AME_n values of MBM and FM as determined by the Replacement method*

Dietary composition of the various test diets for roosters and ostriches are given in Table 1 and Table 2. Feed consumption by ostriches on the MBM test diets increased as MBM levels increased, while similar intakes were measured between the various FM test diets. MBM and FM had no adverse effect on the palatability of diets in roosters as feed intakes remained fairly constant between the various diets.

Results on the DMD, AME and AME_n values of MBM and FM test diets are given in Table 1 and Table 2. These results were used to derive DMD, AME and AME_n values of MBM and FM for ostriches and roosters respectively and are presented in Table 5 and Table 6.

Markedly improved DMD values of 0.629 and 0.532 were observed for MBM at the two dietary levels (200 g/kg and 400 g/kg) as opposed to estimates of 0.406 and 0.293 measured in roosters (150 g/kg and 300 g/kg). DMD values of lucerne in ostriches amounted to 0.519 while that of maize in roosters was calculated as 0.826. As obvious from the improved DMD values, substantially higher AME estimates of 15.18 MJ/kg and 14.08 MJ/kg were computed for ostriches while the congruent values in roosters were 10.06 MJ/kg and 9.16 MJ/kg at the two dietary levels of MBM. AME values for lucerne in ostriches was 10.08 MJ/kg and 14.59 MJ/kg for maize in roosters.

By using the appropriate correction for N-retention (RN), AME_n values in ostriches were reduced to 9.57 MJ/kg, 13.77 MJ/kg and 13.05 MJ/kg for lucerne, MBM at 200 g/kg and MBM at 400 g/kg respectively. AME_n values in roosters were calculated at 14.46 MJ/kg, 8.46 MJ/kg and 7.93 MJ/kg for maize, MBM at 150 g/kg and MBM at the 300 g/kg level of substitution respectively.

As for MBM, significantly improved DMD values were measured for FM in ostriches as opposed to roosters. These values in ostriches were 0.777 and 0.717 at the 250 g/kg and 500 g/kg dietary levels while values of 0.547 and 0.590 were derived for roosters at the two dietary levels of 150 g/kg and 300 g/kg. DMD values for the basal ingredients, lucerne in ostriches and maize in roosters, amounted to 0.501 and 0.800 respectively.

AME values for FM in ostriches were 19.33 MJ/kg and 18.11 MJ/kg while values of 14.20 MJ/kg and 15.67 MJ/kg were measured for roosters. AME values of 9.69 MJ/kg and 14.00 MJ/kg were computed for lucerne in ostriches and maize in roosters.

AME_n values of 15.72 MJ/kg and 15.80 MJ/kg were calculated for FM in ostriches and estimates of 11.52 MJ/kg and 13.62 MJ/kg were measured in roosters. AME_n value of lucerne was 9.16 MJ/kg and that of maize in roosters were calculated as 14.05 MJ/kg.

2. *TME_n values of MBM and FM for ostriches and roosters as determined by multiple regression*

All the slopes representing the indigestible, unmetabolisable energy and unretainable N proportions were significant for MBM, FM and the basal ingredients, lucerne and maize in ostriches and roosters (Table 3 and Table 4). All intercepts were found to be zero in ostriches, hence no estimate of endogenous energy and nitrogen losses could be established. In roosters however intercepts were significant for RN of MBM and for DMD, energy balance and RN of FM. The intercepts for energy retention and RN indicated apparent endogenous losses.

Using the slopes yielded estimates for DMD, TME, RN and TME_n that are given in Table 5 and Table 6. Similar to the results calculated according to the replacement method, DMD values of 0.609 and 0.357 were measured for MBM in ostriches and roosters respectively. DMD values for lucerne in ostriches were 0.568 while an estimate of 0.863 was computed for maize in roosters.

TME values for lucerne and MBM amounted to 10.32 MJ/kg and 13.90 MJ/kg respectively while values of 14.72 MJ/kg and 9.70 MJ/kg were calculated for maize and MBM in roosters. Using the estimates

for RN (g N/kg ingredient), TME_n values were computed as 9.67 MJ/kg and 12.81 MJ/kg for lucerne and MBM in ostriches. Values of 14.38 MJ/kg and 8.34 MJ/kg were measured for maize and MBM in roosters.

The positive digestibility intercept observed for FM in roosters probably resulted in an overestimation of DMD for FM in roosters. This is evident from the substantially higher value of 0.753 derived from the regression method in comparison to the values of 0.547 and 0.590 calculated according to the replacement method. DMD values of 0.719 and 0.491 were calculated for FM and lucerne in ostriches.

TME values amounted to 9.13 MJ/kg and 16.79 MJ/kg for lucerne and FM respectively, while values of 15.28 MJ/kg and 16.35 MJ/kg were measured for maize and FM in roosters respectively. A substantially higher estimate of RN viz. 65.8 g N/kg FM was observed in roosters as opposed to 45.5 g N/kg FM in ostriches. This caused that a significantly improved TME_n value of 15.13 MJ/kg was calculated for ostriches vs. 13.95 MJ/kg estimated for roosters.

DISCUSSION

FM is the dominant animal protein source in poultry diets due to its high quality protein and energy contribution. MBM on the other hand also contain high levels of protein but is known for its variability in protein, fat and ash contents due to the nature of byproducts. In the Little Karoo, South Africa, where substantial quantities of byproducts are available from the locally ostrich abattoir, estimates on the energy contribution of MBM are essential to decide whether MBM could be used as dietary source for ostriches.

Results in the present study verified that MBM would be a economically feasible dietary source for ostriches due to it competitive TME_n content of 12.81 MJ/kg as opposed to 15.13 MJ/kg for FM. For roosters however, significantly reduced MBM values were derived (8.34 MJ/kg), that are markedly lower that reported values for MBM by Dolz and De Blas (1992), Lessire and Leclercq (1983), Lessire, Leclercq, Conan, Hallouis (1985). Results in the present study for MBM are more in agreement to the findings of Allen (1992) and possible variations in chemical composition can account for differences in energy utilisation.

The TME_n value of 13.95 MJ/kg are markedly higher that results reported by Hayes and Du Preez (1994) for South African FM. The fat content of the FM evaluated in the present study was analysed at 120 g/kg vs. 82.50 g/kg reported by Hayes **et al.,** 1994, Which could thus explain the discrepancy.

The reason for the improved TME_n values for FM and MBM in ostriches in comparison to that for roosters is not clear and could possibly be explained by enhanced digestibility of the high fat content in these ingredients.

The substantial variation in AME_n values for MBM and FM in roosters between the two dietary levels of substitution are in agreement to the findings of Lessire **et al.,** 1985. It was obvious for both FM and MBM in roosters and ostriches that the regression method yielded TME_n values with markedly reduced variation, indicating the sensitivity of estimates derived for test ingredients at low dietary levels and the method of calculation. The good fit (R^2) and lower standard error of estimating TME_n according to a multiple regression method in which the individual metabolisabilities of birds were pooled, seemed a more reliable estimate and the findings in the present study support previous findings by Cilliers **et al.,** (1994a; 1994b; 1994c; 1994d; 1994e).

It could be concluded that both the animal protein sources, MBM and FM could make a substantial energy contribution to diets for ostriches. With TME_n estimates for most of the common ingredients used in diets of ostriches, results on the utilisation efficiency of these energy values are now required to establish requirement recommendations for ostriches.

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TABLE 1: DIETARY CHARACTERISTICS OF BALANCE STUDIES WITH MEAT AND BONE MEAL (MBM) FED TO ROOSTERS AND OSTRICHES.

Ostriches	**Diet 1 Lucerne Basal**	**Diet 2 200 g/kg MBM 800 g/kg Lucerne**	**Diet 3 400 g/kg MBM 600 g/kg Lucerne**
Protein, g/kg	175.27	240.10	307.54
Feed intake, kg/bird/day	1.599 ± 0.171	1.613 ± 0.216	1.889 ± 0.147
DMD	0.519 ± 0.00975	0.541 ± 0.0209	0.524 ± 0.0114
AME, MJ/kg	10.08 ± 0.224	11.10 ± 0.254	11.68 ± 0.154
RN, g/bird/day	23 ± 3.97	31 ± 5.41	38 ± 3.99
AME_n, MJ/kg	9.57 ± 0.252	10.41 ± 0.227	10.96 ± 0.141
Roosters	**Diet 1 Maize Basal**	**Diet 2 150 g/kg MBM 850 g/kg Maize**	**Diet 3 300 g/kg MBM 700 g/kg Maize**
Protein, g/kg	87.10	156.90	231.02
Feed intake, g/bird/day	86 ± 2.83	90 ± 4.87	87 ± 6.05
DMD	0.826 ± 0.00214	0.763 ± 0.0107	0.666 ± 0.0109
AME, MJ/kg	14.59 ± 0.0344	13.91 ± 0.133	12.96 ± 0.0737
RN, g/bird/day	0.306 ± 0.0232	0.89 ± 0.123	1.11 ± 0.152
AME_n, MJ/kg	14.46 ± 0.0378	13.56 ± 0.116	12.50 ± 0.0582

TABLE 2: DIETARY CHARACTERISTICS OF BALANCE STUDIES WITH FISH MEAL (FM) FED TO ROOSTERS AND OSTRICHES.

Ostriches	**Diet 1 Lucerne Basal**	**Diet 2 250 g/kg FM 750 g/kg Lucerne**	**Diet 3 500 g/kg FM 500 g/kg Lucerne**
Protein, g/kg	175.27	299.31	397.60
Feed intake, kg/bird/day	1.559 ± 0.134	1.502 ± 0.119	1.516 ± 0.0650
DMD	0.501 ± 0.0113	0.570 ± 0.0129	0.609 ± 0.0182
AME, MJ/kg	9.69 ± 0.242	12.10 ± 0.223	13.90 ± 0.252
RN, g/bird/day	23 ± 2.77	53 ± 4.71	58 ± 3.32
AME_n, MJ/kg	9.16 ± 0.262	10.80 ± 0.202	12.48 ± 0.199
Roosters	**Diet 1 Maize Basal**	**Diet 2 150 g/kg FM 850 g/kg Maize**	**Diet 3 300 g/kg FM 700 g/kg Maize**
Protein, g/kg	90.14	167.50	249.09
Feed intake, g/bird/day	90 ± 2.13	100 ± 3.87	87 ± 4.05
DMD	0.800 ± 0.00696	0.762 ± 0.0136	0.737 ± 0.0160
AME, MJ/kg	14.00 ± 0.109	14.03 ± 0.231	14.50 ± 0.227
RN, g/bird/day	-0.09 ± 0.0399	1.00 ± 0.181	1.62 ± 0.264
AME_n, MJ/kg	14.05 ± 0.0912	13.67 ± 0.178	13.92 ± 0.174

TABLE 3: THE INDIGESTIBLE, UNMETABOLISABLE AND UNRETAINABLE N PROPORTIONS OF MEAT AND BONE MEAL (MBM), MAIZE AND LUCERNE, FED TO ROOSTERS AND OSTRICHES

	Digestibility	Energy Balance	N-Balance
Ostriches			
Intercept	82 ± 63*	0.6 ± 0.981*	4 ± 4.7*
Slope b_1 for lucerne	0.432 ± 0.0402	0.407 ± 0.0362	0.367 ± 0.109
Slope b_2 for MBM	0.391 ± 0.0458	0.160 ± 0.0413	0.634 ± 0.0430
R^2	0.869	0.847	0.904
Roosters			
Intercept	3.1 ± 2.09*	11 ± 23*	0.467 ± 0.221
Slope b_1 for maize	0.137 ± 0.0242	0.147 ± 0.0155	0.331 ± 0.185
Slope b_2 for MBM	0.643 ± 0.0332	0.414 ± 0.0226	0.543 ± 0.0383
R^2	0.929	0.913	0.894

* Estimates marked (*) do not differ from zero ($p > 0.05$)

TABLE 4: THE INDIGESTIBLE, UNMETABOLISABLE AND UNRETAINABLE N PROPORTIONS OF FISH MEAL, MAIZE AND LUCERNE, FED TO ROOSTERS AND OSTRICHES

	Digestibility	Energy Balance	N-Retention
Ostriches			
Intercept	-39 ± 68*	-1.2 ± 1.19*	-11 ± 10.5*
Slope b_1 for lucerne	0.509 ± 0.0435	0.475 ± 0.0437	0.649 ± 0.239
Slope b_2 for fish meal	0.288 ± 0.0623	0.116 ± 0.0547	0.556 ± 0.118
R^2	0.846	0.856	0.546
Roosters			
Intercept	11.3 ± 2.37	171 ± 35.5	0.872 ± 0.256
Slope b_1 for maize	0.0938 ± 0.0242	0.0903 ± 0.0208	0.388 ± 0.187
Slope b_2 for fish meal	0.247 ± 0.0404	0.139 ± 0.0294	0.373 ± 0.0423
R^2	0.675	0.605	0.774

* Estimates marked (*) do not differ from zero ($p > 0.05$)

TABLE 5: DMD, RN, AME, TME, AME_n AND TME_n VALUES FOR MEAT AND BONE MEAL FED TO ROOSTERS AND OSTRICHES

	DMD	RN g/bird/day	AME MJ/kg	AME_n MJ/kg
Ostriches				
a) Replacement Method				
Lucerne Basal	0.519 ± 0.00975	23 ± 3.97	10.08 ± 0.224	9.57 ± 0.252
MBM at 200 g/kg	0.629 ± 0.0745	63 ± 4.40	15.18 ± 0.980	13.77 ± 1.03
MBM at 400 g/kg	0.532 ± 0.0190	61 ± 4.74	14.08 ± 0.092	13.05 ± 0.102
b) Regression Method	**DMD**	**RN g N/kg diet**	**TME MJ/kg**	**TME_n MJ/kg**
Lucerne Basal	0.568 ± 0.0142	17.8 ± 1.08	10.32 ± 0.223	9.67 ± 0.263
MBM	0.609 ± 0.0115	29.9 ± 0.877	13.90 ± 0.171	12.81 ± 0.203
Roosters				
a) Replacement Method	**DMD**	**RN g/bird/day**	**AME MJ/kg**	**AME_n MJ/kg**
Maize Basal	0.826 ± 0.0463	0.306 ± 0.152	14.59 ± 0.185	14.46 ± 0.194
MBM at 150 g/kg	0.406 ± 0.0445	4.2 ± 0.510	10.06 ± 0.558	8.46 ± 0.493
MBM at 300 g/kg	0.293 ± 0.0226	3.0 ± 0.313	9.16 ± 0.159	7.93 ± 0.131
b) Regression Method	**DMD**	**RN g N/kg diet**	**TME MJ/kg**	**TME_n MJ/kg**
Maize Basal	0.863 ± 0.0057	9.3 ± 0.645	14.72 ± 0.0669	14.38 ± 0.0905
MBM	0.357 ± 0.0081	37.3 ± 0.806	9.70 ± 0.0966	8.34 ± 0.126

TABLE 6: DMD, RN, AME, TME, AME_n AND TME_n VALUES FOR FISH MEAL FED TO ROOSTERS AND OSTRICHES

	DMD	RN g/bird/day	AME MJ/kg	AME_n MJ/kg
Ostriches				
a) Replacement Method				
Lucerne Basal	0.501 ± 0.0113	23 ± 2.77	9.69 ± 0.242	9.16 ± 0.262
Fish Meal at 250 g/kg	0.777 ± 0.0617	143 ± 20.6	19.33 ± 1.15	15.72 ± 1.27
Fish Meal at 500 g/kg	0.717 ± 0.0381	93 ± 7.19	18.11 ± 0.558	15.80 ± 0.476
b) Regression Method	**DMD**	**RN g N/kg diet**	**TME MJ/kg**	**TME_n MJ/kg**
Lucerne Basal	0.491 ± 0.0153	9.9 ± 2.36	9.13 ± 0.269	8.77 ± 0.351
Fish Meal	0.712 ± 0.0133	45.5 ± 2.55	16.79 ± 0.222	15.13 ± 0.315
Roosters				
a) Replacement Method	**DMD**	**RN g/bird/day**	**AME MJ/kg**	**AME_n MJ/kg**
Maize Basal	0.800 ± 0.00696	-0.09 ± 0.0399	14.00 ± 0.109	14.05 ± 0.0912
Fish Meal at 150 g/kg	0.547 ± 0.0988	7.2 ± 1.20	14.20 ± 1.02	11.52 ± 1.29
Fish Meal at 300 g/kg	0.590 ± 0.0557	5.6 ± 0.885	15.67 ± 0.798	13.62 ± 0.381
b) Regression Method	**DMD**	**RN g N/kg diet**	**TME MJ/kg**	**TME_n MJ/kg**
Maize Basal	0.906 ± 0.00849	8.8 ± 0.952	15.28 ± 0.124	14.96 ± 0.159
Fish Meal	0.753 ± 0.0101	65.8 ± 1.124	16.35 ± 0.149	13.95 ± 0.190

CHAPTER 11

THE ADDITIVITY OF TME_n VALUES OF VARIOUS INGREDIENTS IN A COMPLETE DIET FOR OSTRICHES (STRUTHIO CAMELUS) AND ADULT ROOSTERS

BY

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ABSTRACT

The additivity and accuracy of TME_n values determined for ostriches and roosters by Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994a) and Cilliers, Hayes, Chwalibog and Du Preez (1994b; 1994c; 1994d; 1994e; 1994f; 1994g; 1994h) were evaluated by feeding an experimental diet comprising a number of these ingredients. The TME_n value of the test diet was determined with 36 young ostriches (7 month old) by balance method of continuous feeding for 5 days. Results in roosters were determined according to the DSQ-method (Du Preez, Duckitt and Paulse, 1986), where the test diet were offered for 3 days after an adaption period of 24 hours.

Theoretical values for the test diet of 11.69 ± 0.189 MJ/kg and 8.28 ± 0.181 MJ/kg for ostriches and roosters respectively, compared favourably to determined values viz. 11.25 ± 0.0724 MJ/kg and 8.02 ± 0.445 MJ/kg. Results in the present study confirmed the accuracy of TME_n values determined by Cilliers **et al.,** (1994b; 1994c; 1994d; 1994e; 1994f; 1994g; 1994h) for ostriches and the fact that values derived from mature birds, are also applicable to younger birds.

It was concluded that reliable energy values are now available for the establishment of energy requirements and diet formulations in ostriches.

INTRODUCTION

Although commercial ostrich farming existed for several years, extrapolated information about poultry nutrition was used due to ignorance on the nutritional features of ostriches. The general practice of using energy values of ingredients derived for poultry to formulate diets for ostriches caused that various nutrition related problems were encountered.

Swart, Mackie and Hayes (1993) observed fermentative capabilities in ostriches and measured substantial quantities of volatile fatty acids (VFA) in the gastro-intestinal tract. It was concluded that VFA production from the digestion of plant fibres such as cellulose and hemicellulose could contribute to the energy requirements of ostriches. These findings were confirmed by Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994a) and Cilliers, Hayes, Chwalibog and Du Preez (1994b; 1994c; 1994d; 1994e; 1994f; 1994g), who conducted various comparative studies between adult roosters and mature ostriches with respect to the true and apparent metabolisable energy contents of various ingredients. TME_n values determined for mature ostriches were also found to be suitable for diet formulation for younger birds (6 month of age) (Cilliers **et al.,** 1994h).

In least cost formulation where metabolisable energy values are assigned to ingredients, independent of the nature of the diet in which it are used, it is assumed that the various values would be additive (Hill, Anderson, Renner and Carew, 1960; Miller, 1974). In order to evaluate this theory for ME values determined for ostriches and roosters, a complete diet comprising various ingredients were formulated according to TME_n values established by Cilliers **etal.,** (1994a; 1994b; 1994c; 1994d; 1994e; 1994f; 1994g).

This paper therefore deals with the evaluation of the additivity (accuracy) of TME_n values of various ingredients in ostriches and roosters.

MATERIAL AND METHODS

Diets and Treatments

Results on TME_n values determined by Cilliers **et al.,** (1994a; 1994b; 1994c; 1994d; 1994e; 1994f; 1994g) were tabulated and used for the formulation of an experimental diet comprising as much of these ingredients as possible (Table 1). The experimental diet contained 7 ingredients and most ingredients were from the same samples used in TME_n evaluations. Fish meal and ostrich meat and bone meal were however taken from new batches.

Lucerne hay, maize, and barley were hammermilled through a 5 mm sieve and the complete diet were then pelleted to minimise wastage. The diet and its calculated contents (TME_n for roosters and ostriches) are given in Table 2.

Animal Husbandry and Experimental Procedures

Ostriches

The same procedure for metabolisable energy determinations with ostriches as described by Cilliers **et al.,** (1994a; 1994b) were used in the present study. Prior to experimentation, an adaption period of 7 days were allowed for adjusting to the experimental diet. Birds were then equipped with excreta collection harnasses and placed in wooden metabolism crates. The experimental diet were allotted among 36 ostriches (7 months of age), with a mean body weight of 70 ± 2.03 kg. Results were obtained by means of balance method where total excreta voided and feed consumption were accurately measured for 5 days. Intakes were restricted at 1000 g, 1500 and 2000 g per day to enable an extended range of energy intakes for regression analises. Water was available at all times.

Roosters

The DSQ-method of Du Preez, Duckitt & Paulse (1986), was used for evaluating the ME content of the experimental diet. Birds were initially starved for 20 hours followed by a 24 hour adaption period. Feed intake and excreta output were then accurately measured for the following 3 days. Daily levels of intake were restricted at 80 g, 110 g and 140 g/bird.

Analytical Procedures

Daily excretions were kept separate and stored at - 10 °C until the termination of trials. Dry daily voidings of excreta were proportionally pooled over days for individual birds and used for analises after fine grounding. Samples were analised for gross energy, using a solid state bomb calorimeter (Model CP 500, Digital Data Systems, P.O. Box 35872, Northcliff, Johannesburg). Nitrogen analysis were done by means of the macro-Kjeldahl method.

Calculations and Statistical Procedures

Apparent metabolisable energy, corrected for N retention (AME_n), were calculated according to Fisher and McNab (1987). Linear models (Cilliers **et al.,** (1994a; 1994b; 1994c), representing undigestible fractions of dry matter, dietary energy and nitrogen were determined. Using the complement of these slopes yielded values for DMD, TME (MJ/kg) and RN (g N/kg diet).

True metabolisable energy content, corrected to N equilibrium (TME_n), was calculated according to the model relating energy excreted (y) as a function to the congruent energy intake (x). The slope yield an

estimate for the unmetabolisable proportion of the diet, hence the complement of the slope (1-b), multiplied by the combustible energy value of the diet, calculate the TME value of the experimental diet. N retention, RN, (g N/kg diet) was then used for the alteration of TME to TME_n, using the energy equivalent factor, 36.5 kJ/g RN.

Results were performed according to Snedecor and Cochran (1986) and conducted by means of SAS statistical software (1985).

RESULTS

Results on determined nutrient contents and digestibilities are given in Table 3. Improved dry matter digestibility (DMD) was observed for ostriches viz. 0.571 as opposed to 0.448 measured for roosters. AME values were 11.93 MJ/kg and 8.67 MJ/kg for ostriches and roosters respectively and these values were altered to 11.10 MJ/kg and 8.20 MJ/kg after correction for RN was applied.

All slopes for the linear models, representing undigestible fractions of dry matter, dietary energy and nitrogen, were significant for both ostriches and roosters (Table 4). No estimates were derived for intercepts ($p>0.05$). DMD according to regression models were 0.609 and 0.479 for ostriches and roosters respectively and TME values of 12.04 MJ/kg and 8.77 MJ/kg were calculated (Table 5). Retention of dietary N was similar in ostriches and roosters (21.7 g N/kg diet vs. 20.5 g N/kg diet). TME_n values for the experimental diet were 11.25 MJ/kg for ostriches and 8.02 MJ/kg for roosters.

DISCUSSION

The effect of feed intake on AME_n determinations is well defined (McNab, 1990). The magnitude of the influence of dietary intake of a test ingredients on AME_n determinations, will depend on substitution levels of the test ingredient in a basal diet. It was evident from results presented by Cilliers **et al.,** (1994a; 1994b; 1994c; 1994d; 1994e; 1994f; 1994g), that substantial differences are observed for a test ingredient between various levels of substitution. AME_n and TME_n generally compared favourably where a test ingredient was used as such (1000g/kg) to compile a test diet.

The regression procedure described by Cilliers **et al.,** 1994a; 1994b) consistently yielded TME_n values with lower variation as AME_n values from the replacement method (1994a; 1994b; 1994c; 1994d; 1994e; 1994f; 1994). It was concluded that the good fit (R^2) of data and the markedly reduced error in estimating TME_n according to regression procedures, where individual metabolisabilities were pooled, should be the method for describing energy values for ostriches.

Hence it was more likely that TME_n values would represent reliable energy values for ostriches. The theoretical TME_n values of the experimental diet amounted to 11.69 MJ/kg and 8.28 MJ/kg for ostriches and roosters respectively. These values compared favourably to the determined values of 11.25 MJ/kg and 8.02 MJ/kg ($p>0.05$) in the present study, confirming the additivity and accuracy of values determined for ostriches and roosters. Results also confirmed previous findings of Cilliers **et al.,** (1994h) that values determined for mature birds, are suitable for diet formulation of younger ostriches.

It was concluded from results in the present study, that reliable energy values are now available for the establishment of energy requirements and dietary formulations in ostriches.

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TABLE 1: SUMMURY OF MEAN TME$_n$ VALUES AS DETERMINED FOR VARIOUS INGREDIENTS IN OSTRICHES AND ROOSTERS

INGREDIENTS	OSTRICHES	ROOSTERS
Yellow maize[a]	15.06 ± 0.228	14.42 ± 0.0567
Lucerne Hay[b]	8.91 ± 0.119	4.03 ± 0.118
Malting barley[c]	13.93 ± 0.251	11.33 ± 0.212
Oats	12.27 ± 0.291	10.63 ± 0.783
Triticale	13.21 ± 0.241	11.82 ± 0.224
Wheat Bran	11.91 ± 0.221	8.55 ± 0.375
Sunflower Oilcake Meal	10.79 ± 0.278	8.89 ± 0.494
Soybean Oilcake Meal	13.44 ± 0.173	9.04 ± 0.165
Saltbush Hay (Atriplex nummularia)	7.09 ± 0.238	4.50 ± 0.271
Common Reed (Phragmites Australis)	8.67 ± 0.337	2.79 ± 0.147
Sweet White Lupinus Albus (CV Buttercup)	14.61 ± 0.340	9.40 ± 0.642
Ostrich Meat and Bone Meal	12.81 ± 0.203	8.34 ± 0.126
Fish Meal	15.13 ± 0.315	13.95 ± 0.190

[a] Mean of 2 measurements in ostriches and 6 in roosters

[b] Mean of 10 measurements in ostriches

[c] Mean of 2 measurements in ostriches

The remainder was determined values in one balance study

TABLE 2: THE COMPOSITION OF THE EXPERIMENTAL DIET FED TO OSTRICHES AND ROOSTERS

Ingredients	Dietary levels (g/kg)
OSTRICHES	
Malting Barley	169.48
Yellow Maize	141.14
Wheat Bran	150.00
Lucerne Hay	400.00
Ostrich Meat and Bone Meal	43.70
Soybean Oilcake Meal	30.00
Fish Meal	61.54
Limestone	0.65
Vitamin/Mineral premix	3.50
Nutrient content	**Calculated***
Protein, g/kg	190.50
TME_n, Ostriches	11.69 ± 0.189
TME_n, Roosters	8.28 ± 0.181

* Calculated according to mean TME_n values reported in Table 1

TABLE 3: DIETARY CHARACTERISTICS AND RESULTS OF A BALANCE STUDY WITH AN EXPERIMENTAL DIET FED TO OSTRICHES AND ROOSTERS

	EXPERIMENTAL DIET	
Protein g/kg	209.88 ± 1.12	
Gross Energy MJ/kg	17.1556 ± 0.0187	
	OSTRICHES	**ROOSTERS**
Feed intake, g/bird/day	1306 ± 49.2	89 ± 5.22
DMD	0.571 ± 0.00749	0.448 ± 0.00956
AME, MJ/kg	11.93 ± 0.0693	8.67 ± 0.146
RN, g/bird/day	28.5 ± 1.32	1.26 ± 0.129
AME_n, MJ/kg	11.10 ± 0.0659	8.20 ± 0.137

TABLE 4: THE INDIGESTIBLE, UNMETABOLISABLE, AND UNRETAINABLE N PROPORTIONS AS DETERMINED BY REGRESSION METHOD FOR AN EXPERIMENTAL DIET FED TO OSTRICHES AND ROOSTERS

	Digestibility	Energy Balance	N-Retention
OSTRICHES			
Intercept	61 ± 51.7*	0.134 ± 0.432*	-0.2 ± 2.71*
Slope b_1	0.391 ± 0.0372	0.298 ± 0.0190	0.354 ± 0.0604
R^2	0.791	0.892	0.560
ROOSTERS			
Intercept	2 ± 5.52*	8 ± 87.3*	0.599 ± 0.523*
Slope b_1	0.521 ± 0.0611	0.489 ± 0.0565	0.391 ± 0.170
R^2	0.924	0.926	0.513

* Estimates do not differ from zero ($p > 0.05$)

TABLE 5: DMD, RN, TME AND TME_n VALUES AS ESTIMATED BY REGRESSION METHOD FOR AN EXPERIMENTAL DIET FED TO OSTRICHES AND ROOSTERS

	OSTRICHES	ROOSTERS
DMD	0.609 ± 0.00668	0.479 ± 0.0231
RN, gN/kg diet	21.7 ± 0.383	20.5 ± 2.16
TME, MJ/kg	12.04 ± 0.0584	8.77 ± 0.366
TME_n, MJ/kg	11.25 ± 0.0724	8.02 ± 0.445

CHAPTER 12

A COMPARATIVE STUDY BETWEEN MATURE OSTRICHES (STRUTHIO CAMELUS) AND ADULT ROOSTERS WITH RESPECT TO THE TRUE AND APPARENT AVAILABILITIES FOR AMINO ACIDS IN AN EXPERIMENTAL DIET

BY

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ABSTRACT

This paper deals with a comparative study between young ostriches (7 months of age) and roosters with respect to the apparent and true availability of amino acids (AAAA, TAAA) in an experimental diet. Significantly improved AAAA and TAAA values were determined in ostriches that varied between 0.780 and 0.862, while values of 0.723 and 0.825 were measured in roosters. No estimate for endogenous amino acid excretion could be established in the regression model relating amino acid input to amino acid excreted. Hence AAAA and TAAA values generally compared favourably, both in ostriches and in roosters. Differences in AAAA and TAAA are thus only the result of different methods of calculation. The availability of dietary protein amounted to 0.646 ± 0.0114 and 0.609 ± 0.0643 for ostriches and roosters respectively. Results in the present study produced evidence that the method for determining metabolisable energy values of ingredients for ostriches (Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994a), is also suitable for the assessment of availability of amino acids. It was concluded that efficient diet formulation for ostriches, requires the accurate assessment of amino acid availabilities for individual ingredients as values derived from poultry would underestimate true values for ostriches.

INTRODUCTION

Accurate data describing the available amino acid content of feed constituents are required for least cost formulation of diets. Amino acid (AA) availability is defined as the digested dietary fraction available for normal metabolic processes (Low, 1990).

It is generally excepted to used the same AA availabilities of ingredients for poultry, also in diet formulation for swine (Low, 1990). It is also general practice to extrapolate information about poultry

for the establishment of feeding principles for ostriches. Improved metabolisable energy values were however observed for most ingredients in ostriches due to fermentative capabilities of dietary fibre (Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994a) and Cilliers, Hayes, Chwalibog and Du Preez (1994b; 1994c; 1994d; 1994e; 1994f; 1994g; 1994h; 1994i).

It would be advantageous to determine whether AA availabilities in roosters would be comparable to that obtained for ostriches. Hence it was decided to conduct a comparable study between ostriches (7 month of age) and adult roosters with respect to the true and apparent availability of amino acids in an experimental diet.

MATERIAL AND METHODS

Diets and Treatments

An high protein experimental diet, comprising 7 ingredients were mixed and pelleted to minimise wastage. The diet and its determined nutrient contents are given in Table 1.

Animal Husbandry and Experimental Procedures

Ostriches

The same balance method used for metabolisable energy determinations in ostriches (Cilliers **et al.,** 1994a; 1994b) was used in the present study. Ostriches weighing on average 70 ± 2.03 kg were selected and received the test diet for a 7 day adjusting period. Birds were then fitted with excreta collection harnesses and placed in wooden metabolism crates. Three levels of daily intake viz. 1000 g, 1500 g and 2000 g were used, while water was continuously available. Feed intake and excreta production was accurately measured for 5 days when the trial was terminated.

Roosters

Ten adult roosters (mean weight 3.2 ± 0.237 kg) were starved for 20 hours prior to an adaption period of 24 hours during which the test diet was offered *ad lib*. This was followed by a 3 day period in which daily intakes were restricted at 80 g, 110 g and 140 g. Feed intake and excreta was collected over the latter period as recommended by Du Preez, Duckitt and Paulse (1986).

Analytical Procedures

Daily excretions were kept separate and stored at - 10 °C until the termination of trials. Dry daily voidings of excreta were proportionally pooled over days for individual birds and used for analises after fine grounding. Nitrogen analysis were done by means of the macro-Kjeldahl method and samples were defattened by ether extraction in a Soxhlet apparatus. Amino acid analyses were determined by ion-exchange chromatography of acid-hydrolysed protein, while methionine and cystine were estimated after oxidation by performic acid. A Beckman amino acid analyser were then used for separating amino acids using lithium and sodium citrate-based buffers (AOAC, 1984).

Calculations and Statistical Procedures

Apparent amino acid (AA) availability (AAAA) is defined as:

(AA intake - AA excreted) * AA intake [1]

AAAA for the various AA's was calculated, for individual birds and mean values reported.

True AA availability (TAAA) is estimated according to a linear model relating AA intake to the proportion excreted:

AA excreted = a + b * AA intake [2]

where the intercept 'a', describe the magnitude of endogenous AA losses while the coefficient 'b' represents the unavailable AA proportion in the diet. Hence TAAA is estimated by the complement of the slope, 1 - b.

Availability of dietary protein and lipid were also determined according to [1] and [2].

Regressions and comparisons were conducted according to Snedecor and Cochran (1986) by means of SAS statistical software (1985).

RESULTS

Results on determined nutrient contents for the test diet are given in Table 1. Mean feed consumption figures for ostriches and roosters were 1306 ± 49.5 and 89 ± 5.22 g/bird/day.

Significant slopes were computed for all the regression models in ostriches and roosters, but intercepts were found to pass through the origin ($p>0.05$). Hence no estimate of endogenous amino acid losses could be established (Table 2).

Significantly improved availabilities for dietary protein were determined for ostriches viz. 0.653 and 0.646 as opposed to values of 0.568 and 0.609 derived for roosters (Table 3). Similarly, improved AAAA and TAAA were also measured for ostriches ($p<0.05$). TAAA for essential amino acids varied between 0.862 and 0.780 with a mean estimate of 0.837 ± 0.00729. TAAA values in roosters ranged between 0.723 and 0.825 with a mean value of 0.795 ± 0.0258.

Mean AA availabilities (AAAA) consistently yielded slightly higher values that those calculated by regression. These differences were however not significant, but reduced variation was observed for TAAA.

Comparable availabilities were measured for dietary lipid in roosters and ostriches that amounted to 0.892 and 0.870 respectively.

DISCUSSION

The utilisation of a balance method for the assessment of AA availability, where AA input is related to the excretion of undigestible proportions, was defined for poultry by Sibbald (1979) and confirmed by Du Preez **et al.,** (1986). The development of a method for the accurate determination of metabolisable energy of feed ingredients in ostriches (Cilliers **et al.,** 1994a; 1994b) was found to be suitable for measuring availability of amino acids.

Improved digestion of dietary amino acids in ostriches, indicated that values derived from poultry, would underestimate the true availability of amino acids for ostriches. Slump, Van Beek, Janssen, Terpestra, Lenis and Smits (1977). confirmed that inter-species prediction of amino acids availabilities could not be made due to substantial species differences. It is possible that the higher availability values in ostriches could possibly be ascribed to the production of *de novo* amino acids. No literature is available on this aspect which requires further investigation.

The inability of regression models to estimate endogenous amino acid secretions, are in support to the findings of Härtel (1986). These workers stated that endogenous losses are characteristic of the method of feeding and are non significant where birds received adequate quantities of feed. Hence estimates for AAAA and TAAA were generally in good agreement, but the regression method yielded values with reduced errors.

Results in the present study indicated that the ostrich has unique digestible features and that the extrapolation of nutritional information from poultry, may result in unrealistic values. Hence diet formulation for ostriches thus requires the accurate assessment of amino acid availabilities for individual ingredients.

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TABLE 1: INGREDIENT AND DETERMINED NUTRIENT CONTENT OF AN EXPERIMENTAL DIET FED TO OSTRICHES AND ROOSTERS

Ingredients	Dietary levels (g/kg)
Marley Barley	169.48
Yellow Maize	141.14
Wheat Bran	150.00
Lucerne Hay	400.00
Ostrich Meat and Bone Meal	43.70
Soybean Oilcake Meal	30.00
Fish Meal	61.54
Limestone	0.65
Vitamin/Mineral premix	3.50
Nutrient content g/kg	
TME_n ostrich, MJ/kg	11.25 ± 0.0724
TME_n roosters, MJ/kg	8.02 ± 0.445
Protein g/kg	209.88 ± 1.12
Lipid, g/kg	32.25 ± 0.478
THR, g/kg	7.00 ± 0.0994
SER, g/kg	6.76 ± 0.171
ALA, g/kg	8.20 ± 0.218
VAL, g/kg	9.60 ± 0.218
MET, g/kg	0.3 ± 0.0609
PHE, g/kg	9.02 ± 0.136
HIS, g/kg	4.53 ± 0.264
LYS, g/kg	11.12 ± 0.220
ILE, g/kg	8.23 ± 0.190
TYR, g/kg	5.36 ± 0.0718
ARG, g/kg	11.24 ± 0.428
CYS, g/kg	3.05 ± 0.218
LEU, g/kg	15.00 ± 0.211

TABLE 2: ESTIMATES FOR THE UNDIGESTIBLE AMINO ACID PROPORTIONS AS ESTIMATED BY REGRESSION FOR AN EXPERIMENTAL DIET FED TO OSTRICHES AND ROOSTERS

Amino acid	Intercept	Slope	R^2
OSTRICHES			
THR	-0.25 ± 0.129*	0.169 ± 0.0144	0.826
SER	-0.20 ± 0.130*	0.151 ± 0.0149	0.778
ALA	-0.06 ± 0.152*	0.0635 ± 0.0142	0.647
VAL	0.16 ± 0.182*	0.138 ± 0.0144	0.786
MET	-0.04 ± 0.0368*	0.184 ± 0.0159	0.830
PHE	-0.06 ± 0.327*	0.191 ± 0.0284	0.618
HIS	-0.11 ± 0.099*	0.146 ± 0.0166	0.794
LYS	-0.05 ± 0.266*	0.168 ± 0.0193	0.760
ILE	-0.12 ± 0.137*	0.171 ± 0.0131	0.855
TYR	-0.09 ± 0.143*	0.184 ± 0.0208	0.721
ARG	-0.44 ± 0.470*	0.220 ± 0.0322	0.634
CYS	-0.03 ± 0.105*	0.194 ± 0.0497	0.795
LEU	-0.22 ± 0.225*	0.141 ± 0.0111	0.852
Protein	-0.20 ± 2.71*	0.354 ± 0.0604	0.560
Lipid	0.537 ± 0.963*	0.130 ± 0.0225	0.536
ROOSTERS			
THR	0.04 ± 0.0169*	0.196 ± 0.0669	0.581
SER	-0.00 ± 0.0123	0.117 ± 0.0589	0.700
ALA	0.00 ± 0.0123	0.081 ± 0.0757	0.532
VAL	0.01 ± 0.0253*	0.190 ± 0.0844	0.560
MET	-0.00 ± 0.0061	0.224 ± 0.109	0.510
PHE	-0.03 ± 0.0172	0.277 ± 0.0595	0.813
HIS	0.01 ± 0.0063*	0.194 ± 0.0556	0.753
LYS	0.00 ± 0.0183*	0.245 ± 0.0459	0.877
ILE	0.01 ± 0.0181*	0.183 ± 0.0706	0.630
TYR	0.00 ± 0.0142*	0.236 ± 0.0728	0.636
ARG	-0.02 ± 0.0117*	0.264 ± 0.0287	0.934
CYS	0.00 ± 0.001*	0.219 ± 0.0254	0.925
LEU	-0.02 ± 0.0312	0.175 ± 0.0652	0.601
Protein	0.599 ± 0.523*	0.391 ± 0.170	0.513
Lipid	0.099 ± 0.039*	0.108 ± 0.0388	0.661

* Estimates do not differ from zero ($p > 0.05$)

TABLE 3: APPARENT AND TRUE AVAILABILITY OF AMINO ACIDS AS ESTIMATED FOR AN EXPERIMENTAL DIET IN OSTRICHES AND ROOSTERS

	OSTRICHES		ROOSTERS	
Amino acid	AAAA	TAAA	AAAA	TAAA
THR	0.861 ± 0.00299	0.831 ± 0.00263	0.774 ± 0.0104	0.804 ± 0.0273
SER	0.874 ± 0.00327	0.849 ± 0.00272	0.814 ± 0.0109	0.823 ± 0.0240
ALA	0.942 ± 0.00270	0.937 ± 0.00410	0.916 ± 0.00518	0.919 ± 0.0437
VAL	0.849 ± 0.00326	0.862 ± 0.00282	0.797 ± 0.0115	0.810 ± 0.0344
MET	0.837 ± 0.00319	0.816 ± 0.00300	0.782 ± 0.0162	0.776 ± 0.0444
PHE	0.815 ± 0.00544	0.809 ± 0.00527	0.748 ± 0.00922	0.723 ± 0.0225
HIS	0.875 ± 0.00502	0.854 ± 0.00362	0.777 ± 0.0637	0.806 ± 0.0210
LYS	0.836 ± 0.00350	0.832 ± 0.00386	0.768 ± 0.00726	0.755 ± 0.0187
ILE	0.842 ± 0.00268	0.829 ± 0.00239	0.814 ± 0.0103	0.817 ± 0.0288
TYR	0.831 ± 0.00399	0.816 ± 0.0374	0.753 ± 0.0106	0.764 ± 0.0257
ARG	0.812 ± 0.00626	0.780 ± 0.00609	0.758 ± 0.00427	0.736 ± 0.0102
CYS	0.814 ± 0.00984	0.806 ± 0.0188	0.766 ± 0.00378	0.781 ± 0.00960
LEU	0.871 ± 0.00240	0.859 ± 0.00206	0.836 ± 0.00910	0.825 ± 0.0246
Protein	0.653 ± 0.0133	0.646 ± 0.0114	0.568 ± 0.0333	0.609 ± 0.0643
Lipid	0.857 ± 0.00464	0.870 ± 0.0041	0.862 ± 0.00543	0.892 ± 0.0174

CHAPTER 13

THE DETERMINATION OF ENERGY, PROTEIN AND AMINO ACID REQUIREMENTS FOR MAINTENANCE AND UTILISATION EFFICIENCIES FOR NUTRIENT RETENTIONS IN OSTRICHES (STRUTHIO CAMELUS)

BY

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ABSTRACT

Requirements for maintenance and the utilisation of dietary protein, amino acids, true metabolisable (TME_n) and effective energy (EE_n) were assessed in 36 young ostriches (7 months of age) by means of comparative slaughter technique and balance method.

One experimental diet were offered to the ostriches at various levels of intake to enable regression analyses for the determination of TME_n and EE_n contents and digestibilities of dietary protein, lipid and amino acids. The TME_n and EE_n values of the diet amounted to 11.25 ± 0.0724 MJ/kg and 8.20 ± 0.320 MJ/kg respectively, while digestibility coefficients for protein and lipid were 0.646 ± 0.0114 and 0.870 ± 0.00411 respectively. Digestibilities of dietary amino acids varied between 0.780 and 0.937 with an mean estimate of 0.837 ± 0.00729.

Response in nutrient gain (energy, lipid, protein and amino acids) in feathers, legs, hides and carcasses were separately studied. Gut fill for each bird was determined and all results were calculated according to empty body weight (EBW).

Various approaches were attempted to establish requirements for maintenance. Metabolisable energy (TME_n) required for maintenance, ME_m, were 0.425 MJ/EBW, $kg^{0.75}$/day and 0.392 MJ/EBW, $kg^{0.75}$/day while maintenance requirements for EE_m, amounted to 0.311 MJ/EBW, $kg^{0.75}$/day. Utilisation efficiencies for ME were estimated as 0.414 ± 0.00644 , 0.426 ± 0.0366 and 0.443 ± 0.0161. While values of 0.568 ± 0.0088 and 0.608 ± 0.0219 were determined for EE.

Requirements for digestible maintenance protein was 0.678 ± 0.0271 g/EBW, kg/day and by altering this estimate to requirement for total dietary protein, 1.05 ± 0.0382 g/EBW, kg/day was calculated. Maintenance requirements (g/EBW, kg/day) for lysine (91 ± 3.79), methionine + cystine (59 ± 0.723), threonine (57 ± 2.39) and valine (65 ± 2.69) compared favourably to values calculated for poultry. Substantially higher values were however determined for leucine (91 ± 3.81), arginine (96 ± 3.98) and histidine (47 ± 1.97).

Gross utilisation efficiency values for digestible amino acids were similar to that observed for poultry and varied between 0.312 ± 0.0185 and 0.477 ± 0.0107. Net utilisation estimates for digestible amino acids varied between 0.948 ± 0.0252 (arginine) for the slow turnover amino acids and 0.569 ± 0.0152 (cystine) for the fast turnover amino acids. A mean net utilisation value of 0.747 were computed for amino acids which was similar to the value revealed for lysine (0.733 ± 0.0163).

Results in the present study presented essential information for the establishment of requirement estimates for ostriches. Further research should be aimed at the studying of protein and lipid growth curves for ostriches.

INTRODUCTION

The domestication of ostriches over the past few years and the commercial farming of ostriches on concentrated diets offered exceptional possibilities (Swart and Kemm, 1985), but various raising difficulties are encountered due to nutritional failures . Literature on ostrich nutrition is severely limiting and to enhance the profitability of ostriches as meat, hide and feather producers, merited the determination of nutrient requirements.

Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994a) and Cilliers, Hayes, Chwalibog and Du Preez (1994b; 1994c; 1994d; 1994e; 1994f; 1994g) conducted a number of balance studies with ostriches in which the TME_n values of most of the common ingredients, used in diets of ostriches, were determined. These values were simultaneously compared to values derived for poultry and significantly improved values were observed for ostriches. The additivity of these TME_n values in a complete diet, compiled by various ingredients, was confirmed by Cilliers, Hayes, Chwalibog and Du Preez (1994h), indicating that reliable metabolisable estimates were now available for ostriches from 6 months to maturity.

The question on the efficiency of utilisation of these energy values are now required to establish requirement recommendations for ostriches. The diet as described by Cilliers **et al.,** 1994h), were

offered to ostriches (7 months of age), for a three week period to establish information on the utilisation efficiencies of dietary energy, protein and essential amino acids by means of comparative slaughter technique.

MATERIALS AND METHODS

Diets and Animal Husbandry

Prior to experimentation, 44 ostriches (7 months of age) were accustomed to weighing procedures, metabolism crates and sampling of excreta (described by Cilliers **et al.,** 1994a; 1994b). At the initiation of the trial a representative sample of 8 ostriches (weighing on average 70 ± 2.03 kg) were sacrificed to estimate the initial carcass characteristics of the remaining birds, used for the response study (weight gain) in the metabolism crates.

One complete diet, comprising 7 ingredients (Table 1) were offered at daily intake levels of 1000 g, 1500 and 2000 g per bird True metabolisable energy, corrected for N retention (TME_n) and apparent amino acid and protein availability were determined by means of balance method for the first 5 days , after an initial adaption period of 7 days (Cilliers **et al**., 1994h; 1994i).

Daily feed intake was accurately measured and precautions were taken to eliminate feed wastage. Water was available at all times. After 21 days, the trial was terminated and a representative sample of 12 birds were selected and killed.

Method of Slaughtering and Sampling.

Birds selected for slaughtering, were killed immediately after weighing. Complete defeathering was conducted by hand and feather weight recorded. Birds were then eviscerated by making a ventral incision posterior to the keel and towards the cloaca. The digestive tract were carefully removed and the gut fill emptied and weighed. Birds were dehide and all subcutaneous lipid was removed. Legs were cut at the femur just above the heel. Precautions were taken to prevent blood losses and collected in plastic bags. This together with lipid removed from the hide and the empty viscera were added to the carcass. The latter can be defined as the proportion of the empty body after removing feathers, the hide and the legs. These 4 body components were individually weighed for the 20 sacrificed birds and stored in plastic bags at -20 °C in a freezer.

Carcasses and legs were cut into small pieces with a band saw after complete freezing took place. The complete legs, hides and carcasses of individual birds were then separately minced in a Wolfmaster

mincer (6 times) and 5 samples per bird per body component were taken for analyses. Samples were then freeze-dried and used for analyses. Feathers were dried in a forced draft oven at 80 °C and representative samples per bird were taken after feathers were hammermilled.

Analytical Procedures

Dried samples were used as such for gross energy (GE) determinations, using a solid state bomb calorimeter (Model CP 500, Digital Data Systems, P.O. Box 35872, Northcliff, Johannesburg). Samples were then defattened with petroleum ether (boiling point 40 to 60 °C) for 14 h and the extracted residue used for protein (Kjeldahl procedure) and amino acid analysis.

Amino acid analyses were conducted by means of ion-exchange chromatography of the acid-hydrolysed protein, while methionine and cystine were determined after oxidation by performic acid. Amino acids were separated on a Beckman, model 6600 amino acid analyser, using lithium- and sodium citrate-based buffers. Procedures used for amino acid determinations were similar to that described by Fisher and Scougall (1982). Ash contents were also determined in a muffle furnace at 560°C.

Calculation and statistical analysis of results

Results on TME_n, protein, lipid, ash and amino acid digestibilities of the test diet were calculated using the regression method (Cilliers **et al.**, 1994g; 1994h).

Models for the determination of energy requirement for maintenance and efficiency of utilisation for energy retention (RE)

a: Metabolisable energy (TME_n)

Empty body weight (EBW) is defined as the live body weight of which the wet gut content was removed. Substantial quantities (between 8 and 15 % of live body weight) of gut fill are observed in ostriches (Swart, Siebrits and Hayes, 1993b) and considerable variation existed between individuals at a specific time (results from the present study). Hence it's essential that EBW should be used in calculations rather than live body weight (LBW).

ME (TME_n) for maintenance is defined as the feed consumption at which no energy retention (RE) is obtained and this can be estimated according to Model [1] (Chwalibog, 1991):

$$RE/EBW, kg^{0.75} = a + b * ME_{intake}/EBW, kg^{0.75} \quad [1]$$

where the coefficient b estimates the efficiency of TME_n utilisation for RE (kpf) in growing birds and $a*b^{-1}$ predicts daily requirements for maintenance (ME_m) per metabolic EBW, kg. The standard error (σ) of these estimate is calculated by differentiation viz.

$$\sigma^2 ME_m = b^{-2}\sigma^2 a + a^2 * b^{-4}\sigma^2 b \quad [2]$$

The reverse model of [1] can also be applied namely (Chwalibog, 1991):

$$ME_{intake}/EBW, kg^{0.75} = a + b * RE/EBW, kg^{0.75} \quad [3]$$

where b^{-1} estimates kpf and the intercept, a, provides an estimate for maintenance (ME_m/EBW, $kg^{0.75}$/day)

Model [4], RE is a function of the congruent intake of ME:

$$RE = a + b * ME_{intake} \quad [4]$$

The coefficient b will estimate the efficiency of ME utilisation for maintenance and RE ((kpf) and $a*b^{-1}$ yields the required mean daily ME_m intake for birds in the present study.

b: Effective energy (EE)

Oldham and Emmans (1990) defined effective energy (EE) as dietary ME available for maintenance and growth (ME - heat production) and calculated EE from the dietary characteristics of a feed ingredient viz.:

$$EE = ME - 4.67*kg\ digested\ protein - 3.8*kg\ faecal\ organic\ matter + 12*kg\ digested\ ether\ extract \quad [5]$$

EE allows for the utilisation of ME of work associated with the digestion and retention of protein and lipid.

Hence by adjusting ME to EE, [1] is altered to:

$$RE/EBW,\ kg^{0.75} = a + b * EE_{intake}/EBW,\ kg^{0.75} \quad [6]$$

where the coefficient b estimates the efficiency of EE_n (N-corrected EE) utilisation for energy deposition as fat and protein tissues (kpf) in growing birds and $a*b^{-1}$ predicts requirements for maintenance (EE_m) per metabolic EBW, $kg^{0.75}$/day.

Emmans and Fisher (1986) proposed a model in which requirements for maintenance energy (EE_m) is calculated according to potential mature defeathered protein weight, (P_m) and current defeathered protein weight (P) :

$$EE_m\ MJ/day = 1.63\ MJ * P_m^{-0.27},\ kg\ * P,\ kg \quad [7]$$

where 1.63 is the EE needed per unit maintenance.

Model [8] represents the response in RE to the total intake of EE:

$$RE = a + b * EE_{intake} \quad [8]$$

The coefficient b will estimate the efficiency of EE utilisation for maintenance and RE (kpf) while $a*b^{-1}$ yields the required mean daily EE_m intake for birds in the present study.

Models for the determination of protein and amino acid requirements for maintenance and efficiency of utilisation for protein and amino acid retentions

The model of Emmans and Fisher (1986) was used to calculate maintenance requirements for total protein (TP_m) and essential amino acids (AA_m), where requirements are expressed as a function of the current (P) and potential mature defeathered protein weights (P_m):

$$AA_m\ g/day = 0.008\ kg * P_m^{-0.27},\ kg * P,\ kg * AAC,\ g \quad [9]$$

where 0.008 represents the ideal protein requirement factor for poultry and AAC the amino acid content in defeathered protein (g/kg protein). Protein and amino acids needed for body maintenance was assumed to have identical composition as that of the empty body.

Daily requirements for maintenance, derived from [9], were also expressed as ratios of mean EBW for the experimental period.

Gross utilisation of TP and AA were calculated by the ratio :

Gross utilisation = Total AA and TP retention / total AA and TP intake [10]

AA_m and TP_m were deducted from congruent intakes to yield retainable AA and TP consumption figures. These estimates were used to derive values for utilisation efficiencies above maintenance (net efficiency):

Net utilisation = Total AA and TP retention / retainable AA and TP intakes [11]

Calculation of metabolic EBW and mean protein weight for the duration of the experimental period

RE and ME_{intake} in models [1] and [3] was expressed as ratios of metabolic EBW for the trial period and in models [7] and [9], mean protein weights for the 21 day experimental period were again required. Both these parameters were assessed by averaging log values of initial and terminal weighings to establish reliable values over the experimental period. This is an improvement of simply taking the geometric mean of the two weighings as the log function corrects for any deviation in maintenance requirements, while the geometric mean assumes a constant requirement per unit body weight.

Simulation of the nutrient contents in the 4 body components

Energy, protein, lipid, ash, moisture and amino acids were determined in feathers, legs, hides and carcasses, respectively (Table 4). Nutrient values for the body components were then proportionally combined according to the established ratios to complete empty body (Table 5). These combined nutrient contents were then used in calculations.

Statistical evaluations were based on Snedecor and Cochran (1986) and conducted by means of the SAS-programme (1985).

RESULTS

Metabolisability of experimental diet (Table 2)

Significant slopes were observed for the linear models relating intake to excreta output for dry matter digestibility (DMD), energy balance, lipid, protein and amino acid digestibilities. No significant slope was computed for ash digestibility, hence ash was omitted from further calculations. All intercepts were non significant ($p>0.05$)

The TME_n content of the experimental diet amounted to 11.25 MJ/kg. The digestibility coefficient (DC) for dietary lipid and protein were 0.870 and 0.646 respectively, while DC for amino acids varied between 0.780 and 0.937 with a mean estimate of 0.837.

Carcass characteristics of the response study (Table 3, Table 4 and Table 5).

As 3 levels of feed input were allowed, an extended range of intakes were obtained with a mean intake of 1.306 kg/bird/day. Substantial differences were observed between the gut fill of the initial and the final group of birds selected for slaughtering and the ratio between gut fill and live body weight declined from 0.12 to 0.8.

Average EBW gain (ADG) amounted to 0.351 kg/bird/day with a feed conversation ratio (feed intake/ADG) of 4.54. Similar ratios of the various body components (feathers, legs and carcasses) to EBW were measured for the initial and final group of birds and were on average 21.48, 63.44 and 862.32 g/kg EBW. A significantly higher ratio of hide/EBW of 55.6 g/kg were recorded for the final group in comparison to 48.5 g/kg measured for the initial group.

Markedly differences were observed between the nutrient contents (energy, dry matter, protein, lipid, ash and amino acids) of feathers, legs, hides and carcasses. Similar nutrient contents per unit of body component were however measured between individual birds ($p>0.05$), hence individual contents were pooled and are presented in Table 4. The combined nutrient contents of the empty body as a unit (feather, legs hide and carcass) and defeathered empty body are given in Table 5. These values were used in calculations.

Energy requirements for maintenance and efficiency of utilisation (Table 6)

Energy retention rate per EBW, $kg^{0.75}$ was estimated at 0.357 MJ/EBW, $kg^{0.75}$/day with a mean energy conversion (MJ intake/MJ deposited) of 1.559 ± 0.0281.

Significant intercepts and slopes were determined for models [1] and [3] (Table 6). Requirements for maintenance (ME_m) amounted to 0.425 MJ/EBW, $kg^{0.75}$/day and 0.392 MJ/EBW, $kg^{0.75}$/day respectively, while similar utilisation efficiencies (kpf) of 0.414 and 0.426 were computed. According to model [4], the daily ME_m for the experimental group of birds was 7.96 MJ/day and kpf was estimated as 0.443.

In the alteration of the ME content of the experimental diet to EE, according to [5], a markedly reduced value of 8.20 MJ/kg was computed and the ratio between EE and ME was 0.729. EE_m amounted to 0.311 MJ/EBW, $kg^{0.75}$ with a kpf value of 0.568 (model [6]). The daily requirements of EE_m for the experimental group of birds were 5.8 MJ/day with a kpf estimate of 0.608 (model [8]). In model [7] where daily EE_m was calculated according to potential mature and current defeathered protein weights, a significantly higher estimate of 8.90 MJ/day was derived for the experimental group of birds.

Maintenance requirements for protein and amino acids and efficiency of utilisation (Table 7)

Retention rates for the various amino acids are listed in Table 8. Retention rates per EBW, $kg^{0.75}$ for protein, lipid and ash amounted to 3.278, 1.427 and 0.630 g/EBW, $kg^{0.75}$/day respectively.

Gross utilisation of amino acids (AA) varied between 0.312 for cystine and 0.556 for arginine with a mean value of 0.435. Daily maintenance requirements for the various amino acids were calculated according to model [9]. These estimates were then presented as ratios of EBW, AA_m g/EBW, kg day viz. for lysine, methionine, cystine, threonine, arginine, leucine and isoleucine, requirements for maintenance were 91, 38, 21, 57, 96, 91, 60 g digestible AA/EBW, kg/day.

In calculating maintenance requirements for protein and amino acids, potential mature defeathered protein weight was required. Results on growth curves for ostriches by Cilliers, Du Preez, Maritz and Hayes (1994i), determined that mature body weight amounted to 120 kg. Using mean ratios for gutfill/LBW, feather weight/EBW and the protein content of defeathered EBW, a mature defeathered protein weight of 20.66 ± 0.901 kg was computed. The maintenance requirement for digestible crude protein amounted to 0.678 g/EBW, kg/day. With a DC for protein of 0.646, total daily dietary protein of 1.05 g/EBW, kg is required for maintenance.

By correcting total AA intakes for AA_m, revealed substantially improved net utilisation figures varying from 0.569 to 0.948 with a mean value of 0.747 for all amino acids. Net utilisation values for lysine, methionine, cystine, threonine, arginine, leucine and isoleucine were 0.733, 0.780, 0.569, 0.710, 0.948, 0.569 and 0.682 respectively.

DISCUSSION

The purpose of nutritional evaluation of feed ingredients is aimed at (Oldham and Emmans, 1990):

1. Determining the extent to which an ingredients will promote growth and production in animals and their provision of essential nutrients.
2. Measuring the utilisation possibilities of various ingredients and the extent to which one ingredient can substitute another to promote animal growth and production.
3. To be able to assess animal performance through nutrition

Nutritional values of feed ingredients for ostriches were till recently unknown, but Cilliers **et al.,** 1994a, 1994b, 1994c, 1994d, 1994e, 1994f, 1994g, 1994h, determined the TME_n content of all common ingredients in diets for ostriches. These values were determined using mature ostriches, but the findings of Cilliers **et al.,** (1994g) confirmed that these values were also applicable to ostriches from 6 months and older. The question however remained to what extent TME_n values are used for maintenance and energy retention.

Significantly improved ME utilisation values (kpf) viz. 0.414, 0.426 and 0.443, were measured in the present study as opposed to a kpf estimate of 0.32 reported by Swart, Siebrits and Hayes (1993a) for ostriches of a similar age. Birds used by Swart **et al.,** (1993a) were weighing between 33.5 and 42 kg, while birds used in the present study weighed between 70 and 75 kg. ME utilisation values (kpf) of ostriches are markedly reduced to values reported in literature for other species viz. 0.72 for broilers (Chwalibog, Sorensen and Eggum, 1985; Chwalibog, 1991), 0.82 for piglets (Huang, Thorbek, Chwalibog and Eggum, 1981) and 0.62 for calves (Thorbek, 1980). Chwalibog (1991) however observed reduced kpf value of 0.52 for chickens (weighing between 0.3 and 1.2 kg live weight) which were more in agreement to the findings in the present study.

The maintenance energy requirements (ME_m) derived in the present study of 0.425 and 0.392 MJ/EBW, $kg^{0.75}$/day, were in agreement to the findings of Swart **et al.,** (1993a), who calculated daily ME_m as 0.44 MJ/live body weight(LBW), $kg^{0.75}$. Degen, Kam, Rosenstrauch and Plavnik (1991) estimated ME_m for ostriches at 1.07 MJ/LBW, $kg^{0.63}$/day and when recalculating these values, it amounted to 0.648 MJ/LBW, $kg^{0.75}$. It should be noted that in both studies ME_m was calculated according to LBW, while in the present study EBW was used.

Swart, Mackie and Hayes (1993c; 1993d), proofed that fermentative digestion of plant fibres could contribute to the energy requirements of ostriches. In the comparative study between ostriches and roosters with respect to TME_n values for various ingredients (Cilliers **et al.,** 1994a, 1994b, 1994c, 1994d, 1994e, 1994f, 1994g, 1994h), it was evident that the improved metabolisabilities observed in ostriches

was probably due to enhanced digestion of the fibrous components. However the utilisation of volatile fatty acids (VFA), produced from fermentative digestion of fibre in ostriches, is unknown and could the reduced kpf estimates be ascribed to impaired utilisation of energy from VFA. This theory was confirmed by the observation of Swart **et al.** (1993a) that efficiency of ME utilisation deteriorated as dietary levels of fibre increased. Similar observations were reported by Eggum and Chwalibog (1982) for rats.

An improved ME retention rate of 0.357 MJ/EBW, $kg^{0.75}$/day were measured in the present study for a diet with a similar nutrient content as that used by Swart **et al.**, (1993a). Retention rate compared more to that reported for broilers of 2 kg (Chwalibog **et al.**, 1985). Swart **et al.**, (1993b), observed that energy conversion (ME, MJ in/MJ retained) increased as birds mature, although feed conversion deteriorates. Swart **et al.**, (1993b) calculated ME conversion rate of 3.63 for birds of 30 kg, while a mean value of 1.56 MJ/kg were derived in the present study for birds weighing between 70 and 75 kg.

Ostriches have the behaviour of constantly consuming stones and foreign objects that could contribute to the ash content of excreta. This probably caused that no significant model could be established between ash intake and that excreted. In the calculation of EE from the dietary characteristics, it was possible that due to variable ash excretion, faecal organic matter (FOM) could be under- or overestimated. As negligible methane losses were observed in ostriches (Swart **et al.**, 1993a), EE for the experimental diet was estimated according to digestible protein, FOM and digestible ether extract (Emmans and Fisher, 1986) and amounted to 0.7287 of the determined ME content. This ratio was substantially lower than 0.94 reported by Emmans and Fisher (1986) for poultry. Using EE intake instead of ME to relate to the congruent RE deposition as lipid and protein tissues, improved kpf to 0.568 and 0.607 which compared more favourably to reported estimates for other species.

Carcass characteristics of defeathered body protein are in agreement to the findings of Du Preez (1991), although reduced levels of lysine, methionine and cystine were determined in the present study. Amino acid contents in body protein also compared favourably to values of Fisher reported by Emmans (1986). Feather protein contents were similar to values reported by Du Preez (1991), but estimates for cystine and leucine were lower in the present study.

Emmans and Fisher (1986) emphasised the importance of distinguishing between feather and body protein growth due to differences in protein retention rates and amino acid contents. Nutrient contents of legs, hides, carcasses and feathers varied substantially and growth in these components revealed a higher rate for hides. This was evident from the higher ratio of hide/EBW in comparison to the other ratios that remained fairly constant between the initial and final group of ostriches. It can be concluded that future research on growth responses in ostriches should be aimed at defining growth in the various components, rather than for the body as a complete unit.

Daily retention rate varies between species, but expressing protein growth in relation to metabolic weight, yields a rather constant value of 6 g protein/W, $kg^{0.75}$/day for all species (Fisher, 1980). This is explained by the rather consistency in the nutrient composition per unit body weight. In ostriches however, protein retention were 3.28 g/EBW, $kg^{0.75}$/day that was similar to rates reported for layers (Fisher, 1980). Since metabolic body weight relate body weight to surface area, and the fact that there is no merit in relating body surface to protein metabolism, requirements for maintenance of amino acids were expressed as functions of EBW.

The determination of maintenance requirements are not well described and various approaches were reviewed by Fisher (1983). Boorman and Burgess (1986) summarised some of the problems associated in estimating requirements for maintenance and concluded that these values served only as guidelines as requirements estimates derived for older birds are not necessarily applicable to younger birds. Although requirements for maintenance expressed per metabolic body surface are more uniform between birds of different sizes, increased basal metabolic processes caused that higher unit requirements for maintenance protein and amino acids are demanded by younger birds (Boorman **et al.,** 1986).

Maintenance requirements (g/kg EBW) for lysine (91), methionine+cystine (59), isoleucine (60), threonine (57) and valine (65) for ostriches compared favourably to values determined for poultry viz. lysine (85), methionine+cystine (60), isoleucine (50), threonine (40) and valine (60). Substantially higher values were however derived for leucine, arginine and histidine in ostriches.

Values derived for gross protein and amino acid retention in ostriches are similar to results presented by Fisher (1980) for poultry and other animals viz. 0.3 - 0.4. Fisher (1980) ascribed the markedly difference between net and gross utilisation figures as the result of imbalances of amino acids in dietary protein. Requirements for maintenance and variability between individuals could account for the remaining differences found for net and gross utilisation efficiency values. Gross utilisation of total protein in ostriches is similar to the findings of Chwalibog **et al.,** (1985) for broilers viz. 0.523.

Net utilisation values for total dietary amino acids in poultry vary between 0.65 and 0.86 (Fisher, 1982). Boorman **et al.,** (1986) suggested a mean utilisation efficiency estimate of 0.7 for total dietary amino acids, while Emmans (1989) recommended the utilisation of a mean value of 0.8 for available amino acids. Baker (1991) estimated a mean utilisation efficiency of 0.76 for digestible amino acids with improved utilisation for slow-turnover amino acids such as lysine (0.80) and impaired utilisation for fast turnover amino acids such as isoleucine (0.61). Net utilisation values of digestible amino acids for ostriches varied between 0.569 and 0.948 with a mean estimate of 0.747. Similar to the findings of Baker

(1991), the fast turnover amino acids showed reduced utilisation efficiencies as opposed to the slow turnover amino acids. Adjusting the net utilisation value of digestible amino acids to net utilisation of total dietary amino acids, by using the mean amino acid digestibility value of 0.826, yielded a reduced value of 0.617.

A number of factors may effect the deposition of protein and amino acids and the utilisation of dietary supply such as inadequate energy levels (Fisher 1980), energy-amino acid interactions (Boorman and Burgess (1986), amino acid imbalances and stage of maturity (Emmans and Fisher, 1986).

Results in the present study were obtained from a response study in which the response in nutrient gains was obtained by means of regulating intakes and not experimental diets. Severe imbalances and unnecessary stress due too diet change were consequently prevented. As birds were used at a stage of maturity at which maximum daily gain were achieved (Cilliers, 1994j), it could be concluded that the utilisation values and requirements for maintenance would also be reliable for extrapolating to ostriches of other age groups. Chwalibog **et al.,**(1985) adapted a similar approach in which maximum nitrogen retention with maximum nitrogen utilisation efficiency were used to reveal maximum nitrogen requirements for broilers.

Results in the present study presented new evidence which could assist in the estimation of the energy and amino acid requirements for ostriches in various growth stages. More work are however required to establish protein and lipid growth curves for ostriches where growth in the various body components are defined.

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TABLE 1: INGREDIENT AND DETERMINED NUTRIENT CONTENT OF AN EXPERIMENTAL DIET FED TO OSTRICHES (7 MONTHS OF AGE)

Ingredients	Dietary levels (g/kg)
Malting Barley	169.48
Yellow Maize	141.14
Wheat Bran	150.00
Lucerne Hay	400.00
Ostrich Meat and Bone Meal	43.70
Soybean Oilcake Meal	30.00
Fish Meal	61.54
Limestone	0.65
Vitamin/Mineral premix	3.50
Nutrient content g/kg	
Protein g/kg	209.88 ± 1.12
Ether extract, g/kg	32.25 ± 0.478
Ash, g/kg	76.11 ± 0.305
Threonine, g/kg	7.00 ± 0.0994
Serine, g/kg	6.76 ± 0.171
Alanine, g/kg	8.20 ± 0.218
Valine, g/kg	9.60 ± 0.218
Methionine, g/kg	3.01 ± 0.160
Phenylalanine, g/kg	9.02 ± 0.136
Histidine, g/kg	4.53 ± 0.264
Lysine, g/kg	11.12 ± 0.220
Isoleucine, g/kg	8.23 ± 0.190
Tyrosine, g/kg	5.36 ± 0.0718
Arginine, g/kg	11.24 ± 0.428
Cystine, g/kg	3.05 ± 0.218
Leucine, g/kg	15.00 ± 0.211

TABLE 2: RESULTS ON THE DIGESTIBILITY OF ENERGY (TME_n), PROTEIN, ETHER EXTRACT AND AMINO ACIDS AS ESTIMATED BY REGRESSION METHOD FOR AN EXPERIMENTAL DIET FED TO OSTRICHES

Nutrients	
DMD	0.609 ± 0.00668
RN, g N/kg diet	21.7 ± 0.383
TME, MJ/kg	12.04 ± 0.0584
TME_n, MJ/kg	11.25 ± 0.0724
Protein DC	0.646 ± 0.0114
Ether Extract DC	0.870 ± 0.00411
Threonine	0.831 ± 0.00263
Serine	0.849 ± 0.00272
Alanine	0.937 ± 0.00410
Valine	0.862 ± 0.00282
Methionine	0.816 ± 0.00300
Phenylalanine	0.809 ± 0.00527
Histidine	0.854 ± 0.00362
Lysine	0.832 ± 0.00386
Isoleucine	0.829 ± 0.00239
Tyrosine	0.816 ± 0.0374
Arginine	0.780 ± 0.00609
Cystine	0.806 ± 0.0188
Leucine	0.859 ± 0.00206

TABLE 3: RATIOS BETWEEN BODY COMPONENTS FOR THE INITIAL AND FINAL GROUP OF OSTRICHES USED FOR CARCASS ANALYSIS

	INITIAL GROUP	FINAL GROUP
Live body weight, kg	70.0 ± 2.03	74.7 ± 1.82
Wet gut content, kg	8.579 ± 0.726	5.876 ± 0.329
Empty body weight (EBW), kg	61.4 ± 2.18	68.8 ± 1.91
Feather/weight (EBW), g/kg	22.5 ± 0.700	20.8 ± 0.765
Leg/weight (EBW), g/kg	63.8 ± 2.62	63.2 ± 2.01
Hide/weight (EBW), g/kg	48.5 ± 1.71	55.6 ± 1.43
Carcass weight/EBW, g/kg	865.2 ± 3.77	860.4 ± 2.99

EBW = Live body weight - Wet gut weight
Carcass weight = EBW - feather weight - Leg weight - Hide weight

TABLE 4: CARCASS CHARACTERISTICS OF VARIOUS BODY COMPONENTS VIZ. HIDE, LEGS, CARCASS AND FEATHERS OF OSTRICHES

Nutrient content g/kg	Hide	Legs	Carcass	Feathers
Gross Energy, MJ/kg	26.403 ± 0.111	16.325 ± 0.156	23.150 ± 1.26	21.554 ± 0.0865
Dry Matter, g/kg	395 ± 3.24	533 ± 2.097	331 ± 2.97	824 ± 10.2
Protein g/kg	247 ± 1.77	268 ± 2.492	190 ± 1.40	713 ± 9.76
Ether extract, g/kg	131 ± 3.79	79.7 ± 2.695	80.9 ± 2.99	8.50 ± 0.355
Ash, g/kg	9.8 ± 1.24	145 ± 3.37	37.9 ± 0.719	21.1 ± 2.28
THR, g/16 g N	2.530 ± 0.0488	2.171 ± 0.0367	3.576 ± 0.0452	5.41 ± 0.140
SER, g/16 g N	3.144 ± 0.0563	2.647 ± 0.0511	3.020 ± 0.0544	7.84 *
ALA, g/16 g N	3.580 ± 0.121	2.614 ± 0.251	6.414 ± 0.0878	3.953 ± 0.214
VAL, g/16 g N	2.980 ± 0.0345	2.571 ± 0.0476	4.277 ± 0.0512	8.500 ± 0.0996
MET, g/16 g N	1.160 ± 0.0159	1.040 ± 0.0183	2.053 ± 0.0202	0.26 *
PHE, g/16 g N	3.240 ± 0.0709	2.629 ± 0.0474	4.480 ± 0.131	3.469 ± 0.111
HIS, g/16 g N	1.763 ± 0.111	1.597 ± 0.0408	2.758 ± 0.0847	0.70 *
LYS, g/16 g N	4.847 ± 0.0991	3.720 ± 0.0571	6.747 ± 0.108	1.270 ± 0.0378
ILE, g/16 g N	2.312 ± 0.0296	1.921 ± 0.0297	3.876 ± 0.0526	5.045 ± 0.0601
TYR, g/16 g N	2.003 ± 0.0621	1.547 ± 0.0300	3.107 ± 0.0710	3.154 ± 0.0293
ARG, g/16 g N	6.955 ± 0.271	5.724 ± 0.187	6.908 ± 0.250	5.542 ± 0.279
CYS, g/16 g N	0.862 ± 0.0379	0.596 ± 0.00885	0.895 ± 0.0217	5.638 ± 0.106
LEU, g/16 g N	4.638 ± 0.0547	3.937 ± 0.0600	6.777 ± 0.0781	8.682 ± 0.0916

* Taken from results presented by Du Preez (1991)

TABLE 5: CARCASS CHARACTERISTICS OF DEFEATHERED EMPTY BODY AND COMPLETE EMPTY BODY (INCL. FEATHERS

Nutrient content g/kg	Defeathered EBW	Complete EBW
Gross Energy, MJ/kg	22.391 ± 1.102	22.854 ± 1.10
Dry Matter, g/kg	340.1 ± 2.865	357.8 ± 3.08
Protein g/kg	193.9 ± 1.459	209.2 ± 1.67
Ether extract, g/kg	81.7 ± 2.949	81.9 ± 2.96
Ash, g/kg	42.4 ± 0.899	42.9 ± 0.948
THR, g/16 g N	3.355 ± 0.044	3.471 ± 0.047
SER, g/16 g N	2.938 ± 0.053	3.106 ± 0.053
ALA, g/16 g N	5.886 ± 0.098	5.971 ± 0.103
VAL, g/16 g N	4.008 ± 0.049	4.191 ± 0.051
MET, g/16 g N	1.898 ± 0.019	1.903 ± 0.019
PHE, g/16 g N	4.201 ± 0.120	4.275 ± 0.122
HIS, g/16 g N	2.573 ± 0.081	2.588 ± 0.081
LYS, g/16 g N	6.310 ± 0.102	6.337 ± 0.103
ILE, g/16 g N	3.586 ± 0.049	3.695 ± 0.050
TYR, g/16 g N	2.883 ± 0.066	2.951 ± 0.067
ARG, g/16 g N	6.687 ± 0.242	6.806 ± 0.248
CYS, g/16 g N	0.855 ± 0.021	0.976 ± 0.024
LEU, g/16 g N	6.338 ± 0.074	6.525 ± 0.076

TABLE 6. DETERMINATION OF METABOLISABLE ENERGY REQUIREMENT FOR MAINTENANCE (ME_m) AND EFFICIENCY OF ME UTILISATION (kpf) FOR ENERGY RETENTION (RE)

a. RE, MJ/EBW, $kg^{0.75}$ = 0.176 (± 0.0178) + 0.414 (± 0.0223) * MEI/EBW, $kg^{0.75}$

R^2 = 0.970 CV = 2.4 %

ME_m = 0.176/0.414 = 0.425 MJ ± 0.00237/EBW, $kg^{0.75}$

kpf = 0.414 ± 0.00644

b. MEI, MJ/EBW, $kg^{0.75}$ = -0.392 (± 0.0640) + 2.348 (± 0.127) * RE/EBW, $kg^{0.75}$

R^2 = 0.971 CV = 3.2 %

ME_m = 0.392 (± 0.0185) MJ/EBW, $kg^{0.75}$

kpf = 1/2.348 = 0.426 ± 0.0366

c. RE, MJ = 3.528 (± 1.01) + 0.443 (± 0.0557) * MEI, day

R^2 = 0.862 CV = 4.51 %

ME_m = 3.528/0,443 = 7.964 ± 0.00620 MJ/day

kpf 0.443 ± 0.0161

TABLE 7. DETERMINATION OF EFFECTIVE METABOLISABLE ENERGY (EE) REQUIREMENT FOR MAINTENANCE (EE_m) AND EFFICIENCY OF UTILISATION (kpf) FOR ENERGY DEPOSITION AS LIPID AND PROTEIN TISSUES

a. RE, MJ/EBW, $kg^{0,75}$ = 0.176 (± 0.0098) + 0.568 (± 0.0305) * EEI/EBW, $kg^{0.75}$

R^2 = 0.950 CV = 6.4 %

ME_m = 0.176/0.568 = 0.311 MJ ± 0.00348/EBW, $kg^{0.75}$

kpf = 0.568± 0.0088

b. EE required for maintenance

EE_m, MJ/day = $P_m^{-0,27}$,kg * $P_{,kg}$ * 1.63 MJ/unit

= $20.66^{-0,27}$ * 12.48 (± 0.363) * 1.63

= 8.980 ± 0.227 MJ/day (Mean for 12 Birds)

c. RE, MJ = 3.527 (± 0.516) + 0.608 (± 0.0762) * EEI, day

R^2 = 0.864 CV = 7.51 %

ME_m = 3.528/0.608 = 5.801 ± 0.00738 MJ/day

kpf 0.608 ± 0.0219

TABLE 8: MAINTENANCE REQUIREMENTS, RETENTION RATES AND EFFICIENCY OF UTILISATION OF VARIOUS NUTRIENTS IN OSTRICHES

Nutrient content g/kg	g/Day Maintenance requirement	mg/EBW, kg/day Maintenance requirement	g/Day Retention rates	mg/EBW, kg/day Retention rate	Gross efficiency of utilisation	Net efficiency of utilisation
Energy			8.2 ± 0.372*	358 ± 6.82[a]		
Protein	44.1 ± 1.19	678 ± 27.1	75 ± 3.06	3276 ± 58.01[a]	0.523 ± 0.0270	0.672 ± 0.0152
Lipid			33 ± 3.25	1442 ± 52.18[a]		
Ash			14.4 ± 0.875	629 ± 14.95[a]		
THR	3.727 ± 0.110	57 ± 2.39	3.904 ± 0.137	60 ± 2.75	0.429 ± 0.0101	0.710 ± 0.0199
SER	3.420 ± 0.100	53 ± 2.18	3.655 ± 0.104	56 ± 2.30	0.395 ± 0.00927	0.615 ± 0.0344
ALA	5.577 ± 0.167	86 ± 3.60	6.654 ± 0.209	102 ± 4.40	0.550 ± 0.0127	0.968 ± 0.0537
VAL	4.195 ± 0.124	65 ± 2.69	4.697 ± 0.178	72 ± 3.46	0.359 ± 0.0114	0.702 ± 0.0369
MET	2.447 ± 0.0729	38 ± 1.57	2.124 ± 0.0673	33 ± 1.41	0.453 ± 0.0113	0.780 ± 0.0197
PHE	4.396 ± 0.129	68 ± 2.81	4.830 ± 0.138	74 ± 3.04	0.419 ± 0.00932	0.654 ± 0.0241
HIS	3.065 ± 0.0909	47 ± 1.97	2.896 ± 0.0883	45 ± 1.89	0.474 ± 0.0104	0.877 ± 0.0408
LYS	5.903 ± 0.175	91 ± 3.79	7.102 ± 0.217	109 ± 4.63	0.486 ± 0.0110	0.733 ± 0.0163
ILE	3.895 ± 0.116	60 ± 2.51	4.126 ± 0.136	63 ± 2.80	0.383 ± 0.00936	0.682 ± 0.0386
TYR	3.324 ± 0.0989	51 ± 2.14	3.299 ± 0.104	51 ± 2.19	0.477 ± 0.0107	0.904 ± 0.0461
ARG	6.225 ± 0.183	96 ± 3.98	7.700 ± 0.221	118 ± 4.86	0.556 ± 0.0108	0.948 ± 0.0252
CYS	1.381 ± 0.0407	21 ± 0.884	1.212 ± 0.0585	19 ± 1.05	0.3120 ± 0.0185	0.569 ± 0.0152
LEU	5.924 ± 0.176	91 ± 3.81	7.244 ± 0.266	111 ± 5.24	0.359 ± 0.00851	0.569 ± 0.0263

Maintenance requirements is requirements of digestible nutrients

Mean EBW for the experimental period 64.999 ± 1.909 kg

* Unit for energy retention rate, MJ/day

[a] Protein, lipid and ash retention rates, mg/EBW, kg 0,75/day and energy retention is kJ/EBW, kg 0.75/day

CHAPTER 14

GROWTH CURVES OF OSTRICHES (STRUTHIO CAMELUS) FROM OUDTSHOORN IN SOUTH AFRICA

BY

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ABSTRACT

Growth results of 43 ostrich males and females were used to compile growth parameters of a flock that is representative of Oudtshoorn birds, using the Gompertz model. Growth results comprise 19 recordings of body weight for each individual commencing from dayold to day 520. Individual fits of data to the growth model were exceptionally good, resulting in low CV values of 2.08 % and 2.84 % for the mean values of all estimates of mature live weight for male and females respectively. The estimated mean mature body weights for the flock were 119.2 kg for males and 122.3 kg for females. Rates of maturing were 9100 and 8500 for males and females respectively which corresponded to ages of 180.83 and 199.2 days at which maximum gain in weight were achieved. None of these parameter estimates differed significantly between sexes. Results in the present study suggested substantial adjustments to growth parameters for Oudtshoorn ostriches published by Du Preez **et al.,** (1992.)

INTRODUCTION

The increased worldwide interest in ostriches and their potential as both hide and meat producers, emphasise the necessity to obtain reliable estimates for growth curve parameters to use in future research.

Du Preez, Jarvis, Capatos and De Kock (1992), described the growth curve of Oudtshoorn ostriches, but expressed their concern that the number of measurements on these birds were inadequate to describe the potential of the population. In their conclusions it was suggested that six intervals of weighing should be increased and that apart from the number of measurements required, the age of weighing should also be increased beyond 400 days.

In this study an attempt was made to describe the growth curves of male and female ostriches, using more data, and to present new information on a flock that is representative of "Oudtshoorn" birds.

MATERIAL AND METHODS:

Animal husbandry

The birds and facilities at the Oudtshoorn Experimental Station were used for this study. The first chickens after mating in late June, normally hatch in early August. Chickens used in this study were selected from the mid September hatch. They were artificially hatched in an incubator and vent sexed at dayold. Seventy birds, 35 males and 35 females, were selected at random. At 10 months of age the sexing could be verified and only one sexing error was found.

Chicks were reared in floor pens in a semi-environmentally controlled chicken house from dayold to 2 months of age. From weekold, chicks were allotted to small outdoor camps (6 m x 10 m) on lucerne pastures, during the day. In the chicken house overhead radiant heaters with temperature controllers were used to ensure that ambient temperatures remained between 23°C and 25°C.

When birds reached 2 months of age, they were moved to bigger lucerne camps (6 m x 50 m). The size of these camps were again adjusted at 3 months to 6 m x 200 m and at 4 months to 50 m x 250 m. At 5 months, birds were removed from lucerne pastures and assigned to two identical feedlots (25 m x 25 m) and they remained in these camps till the termination of this study.

Males and females were kept as one group throughout the study. Feed and water were available at all times. Six diets were offered to the birds during the experimental period viz. pre starter (0-2 months), starter (2-4 months), grower (4-6 months), finisher (6-10 months), post finisher (10-14 months) and maintenance (14-18 months) diets. Diets were formulated according to standards currently used and the composition and approximate analyses of these diets are given in Table 1. The normal management and raising procedures for ostriches as used at this institution were applied. Birds were regularly dosed for internal parasites and vaccinated against Newcastle disease.

At the age of 13 months an unfortunate incident caused the mortality of 17 birds, 10 males and 7 females. It occurred as birds were taken from the feedlots to be weighed. They started a running display ending disastrously. From retrospective evaluation it was similar to a display described by Hurxthal, (1979), as a rare ambiguous behaviour performance stimulated by either fear or play. This

caused birds to scatter and run free for a distance of at least six kilometres. After they were eventually herded and retrieved, various injuries were observed and euthanasia was an inevitable option. The remainder were in good condition and still suitable for the completion of this growth study. Apart from this incident, mortalities were recorded and was normal.

One male which was weighed till the last recording date was eliminated because of an abnormal weight loss during the final three weighings, probably due to an eye injury. For the final statistical analyses, complete sets of data for 26 male and 17 females were available. These comprise 19 recordings of body weight for each individual, commencing at day 1 until day 520. All the birds were individually weighed on each weighing occasion and the sequence for apprehending and taking individuals to the weighing platform, was random. Weight recordings were conducted at the ages of days 1, 30, 56, 85, 113, 140, 168, 219, 242, 269, 299, 327, 352, 383, 410, 443, 473, 499 and 520. The mean concentrate feed intake of birds were also recorded at these weighings. Records were kept and notes made of every observation or incident pertaining to the flock of birds throughout the study.

Statistical analyses and calculation of parameters

The SAS NLIN procedure (SAS Institute, 1985) was implemented to fit Gompertz curves to the collected data, which consisted of sex, age and weight of each bird. Each individual's weighing data was used to fit a curve to obtain estimates of the maximum weight at maturity (A) and the rate of growth (B), also referred to as rate of maturing. The curves were forced to pass through the mean hatching weights of all individuals, leaving A and B to be estimated, thus applying the same form of the Gompertz equation that were used by Du Preez **et al.**,(1992). The time of maximum daily weight gain was then computed by using the estimated parameters for A and B. The various estimates for these parameters were then compared between birds by t-test (SAS Institute, 1985).

RESULTS

The growth parameters of Oudtshoorn ostriches are presented in Table 2 together with the findings of Du Preez **et al.,** (1992) for a smaller flock of Oudtshoorn ostriches.

The estimated mean mature weight for males was 119.2 kg ± 2.483 and 122.3 kg ± 3.468 for females. This amounted to low coefficients of variation (CV's), 2.08 % for males and 2.84 % for females. The growth rate for males was 9.10 ± 0.278 and 8.55 ± 0.412 for females as shown in Table 2. The corresponding age at which maximum growth will be attained was 180.8 days for males and 199.2 days for females. All the parameters estimated in the present study were not

significantly different between sexes ($p>0.05$). The mean cumulative levels (kg/bird/period) of concentrate feed intake at the various stages of weighing (viz. from 30 days to 520 days) were 7, 18, 34, 51, 77, 108, 160, 190, 239, 287, 331, 383, 436, 478, 553, 630, 695, and 741.

DISCUSSION

It is generally accepted in most animals that the age of maximum growth, usually occurs at one third of the age before maturity. From the inflection point of the curves for the male and female birds in this study, the expected ages of maturity would be 602 and 664 days respectively, assuming that the rule also holds for ostriches in general. Since the birds were only weighed until 520 days it can be deduced that the birds in this study were not fully matured when the study was terminated.

The actual mean maximum weight (final weighing) for males were 115 kg and 114 kg for females. This may be further support to the suggestion that a stage of maturity was not completely reached in this population since the estimated mature body weight of both sexes from the Gompertz fit viz. 119 kg and 122 kg were higher than the actual means. However the new knowledge from this study is considered adequate to propose substantial adjustments to the previously published estimates concerning mature weight parameters reported by Du Preez **et al.,** (1992) for Oudtshoorn ostriches.

Comparing these results shows significant ($p<0.05$) lower estimates of 102.1 kg and 98.4 kg for mature body weights of male and female birds by Du Preez **et al.,** (1992) than the values obtained in the present study.

Regarding the rate of maturity, no significant deviation ($p<0.05$) between the findings of Du Preez **et al.,** (1992) and estimates in the present study could be shown. Their estimates were 9.7 ± 0.430 and 9.0 ± 0.44 for males and females respectively vs. estimates of 9.1 ± 0.278 and 8.5 ± 0.412 in the present study. The calculated ages at which maximum weight gain occurred, as reported by Du Preez **et al.,** (1992), were substantially earlier at 163 and 175 days for males and females as opposed to 181 and 199 days in the present study.

A graphs of the growth curves for males and females combined, using the estimates of parameters obtained in this study, is shown in figures 1.

The benefit of using a Gompertz curve to describe the growth of animals is its multiple uses in production and research as demonstrated by a study published by Emmans, (1989). It may be use as a tool to measure the standard of management and feeding against the potential growth of the

animal. It could be utilised for statistical comparisons of measured growth characteristics between birds to help in the selection of progeny for future breeding.

Questions may arise as to qualifying the effect of intensity of feeding or nutritional standards on the rate of growth. Different hypothesis could be formulated and put to the test in future research programs to quantify such effects. An appropriate study would be to determine to what extent the quantitative restriction of a limiting amino acid, to various degrees, would influence the growth rate of a bird. When carcass analyses, which would be a very expensive but worthwhile project, are combined with growth curve studies, the role of amino acids in a growth model can be studied.

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TABLE 1: DIETARY CHARACTERISTICS AND APPROXIMATE ANALYSIS OF NUTRIENT CONTENTS OF DIETS OFFERED TO OSTRICHES FROM DAYOLD TO MATURITY

Ingredients (g/kg)	0 - 2 Months Pre-Starter	2 - 4 Months Starter	4 - 6 Months Grower	6 - 10 Months Finisher	10 - 14 Months Post Finisher	14 Months unwards Maintenance
Lucerne hay	22.7	260.0	428.0	812.0	884.6	420.0
Yellow maize	577.0	501.3	463.5	172.7	100.0	0
Maize oil	20.0	20.0	0	0	0	0
Soybean oilcake meal	232.0	86.0	30.0	0	0	0
Fish Meal	120.0	106.0	59.0	0	0	8.9
Dicalcium Phosphate	5.3	7.2	11.0	11.0	11.2	15.0
Limestone	17.0	12.3	3.0	0	0	0
Methionine	1.0	2.2	1.0	1.8	1.7	1.6
Ostrich Vitamin/Mineral premix	4.5	4.5	4.5	2.5	2.5	2.5
Zincbacitracin 10 %	0.5	0.5	0	0	0	0
Lucern straw	0	0	0	0	0	552.0
Nutrient content						
AME_n MJ/kg (ostrich)	12.5	11.5	10.5	9.2	8.5	7.0
Protein g/kg	230.0	190.0	155.0	140.0	120.0	100.0
ARG	12.0	9.5	7.0	5.5	4.2	3.2
LYS	12.8	11.0	7.8	5.8	4.5	3.0
MET	5.0	4.5	3.5	3.0	2.5	1.1
TSA*	9.0	7.0	5.5	4.5	3.5	1.6
THR	7.5	6.0	4.2	3.1	2.3	1.7
Calcium	14.0	14.0	12.0	12.0	10.0	10.0
Phosphorus (available)	4.3	4.3	3.8	3.8	3.5	3.2

* Total Sulphur containing amino acids (methionine + cystine)

TABLE 2: GROWTH CURVE PARAMETERS FOR MALE (M) AND FEMALES (F) IN AN OUDTSHOORN OSTRICH FLOCK

Mean of estimates from individual birds for sexes	Mature weight (kg)	Rate of maturing (X 1000)	Age of maximum weight gain (days)	Weight at hatching (kg)
Males	119.22 ± 2.483	9.10 ± 0.278	180.83 ± 6.174	0.868 ± 0.0012
Females	122.30 ± 3.468	8.50 ± 0.412	199.20 ± 11.084	0.866 ± 0.0017
*Males	102.1 ± 3.72[a]	9.7 ± 0.43	163	0.813
*Females	98.4 ± 4.2[a]	9.0 ± 0.44	175	0.780
Number of birds in flock: for the present study :	M = 26 F = 17	Number of weighing dates per bird = 19		

* Results from Du Preez et al., 1992

Estimates within the same column with common or no superscripts do not differ significantly ($p > 0.05$)

GROWTH CURVE OF OUDTSHOORN OSTRICHES
AND ESTIMATED CONFIDENCE LIMITS

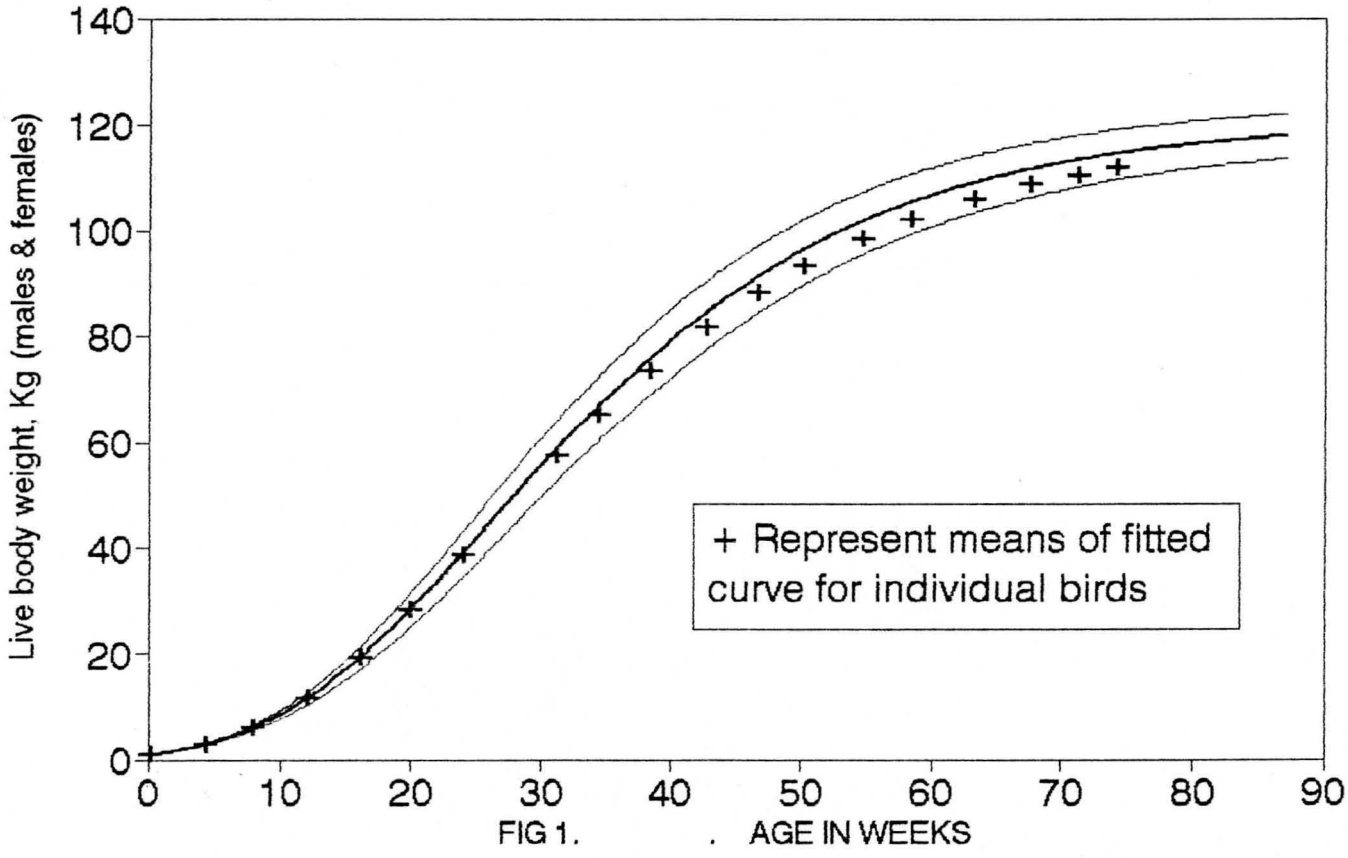

FIG 1.

CHAPTER 15

ENERGY, PROTEIN AND AMINO ACIDS REQUIREMENTS OF OSTRICHES (STRUTHIO CAMELUS) FROM DAYOLD TO MATURITY AS EXTRAPOLATED FROM A RESPONSE STUDY WITH OSTRICHES (7 MONTHS OF AGE)

BY

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ABSTRACT

Results by Cilliers, Hayes, Chwalibog and Du Preez (1994j) on carcass characteristics, requirements for maintenance, utilisation efficiencies and digestibility of dietary nutrients for 7 month old ostriches, were used for the calculation of dietary requirements for these birds (day 210 to day 240). Results on the various body components were extrapolated to assess dietary requirements of metabolisable energy, effective energy, protein and all the essential amino acids for ostriches from dayold to day 600. Two methods were applied for the calculation of requirement recommendations. The validity of extrapolating results from one age group of ostriches to another is discussed. It was concluded that the calculated dietary nutrient levels for ostriches should be suitable for diet formulation for ostriches from day 150 to day 600.

INTRODUCTION

Commercial farming with ostriches in feedlots on concentrated diets require the establishment of nutrient requirements to achieve maximum growth rate on minimum balanced inputs. The general practice of using nutritional values of ingredients and nutrient standards suggested for poultry in diet formulation for ostriches, may result in unprofitable malnutrition (Swart, Siebrits and Hayes, 1993a). This suggestion was confirmed by Cilliers, Hayes, Maritz, Chwalibog and Du Preez (1994a) and Cilliers, Hayes, Chwalibog and Du Preez (1994b; 1994c; 1994d; 1994e; 1994f; 1994g; 1994h) who conducted various comparative studies between poultry and ostriches with respect to the TME_n contents of ingredients generally used in diets for ostriches. Substantially improved TME_n values were derived for ostriches as opposed to values determined for roosters.

Cilliers, Hayes, Chwalibog and Du Preez (1994j) determined requirements for maintenance and utilisation efficiencies of energy, protein and amino acids in a response study with young ostriches (7 months of age). Utilisation values of amino acids compared favourably to values determined for roosters, while reduced utilisation figures were calculated for metabolisable and effective energy.

Results obtained by Cilliers **et al.,** (1994j) were used to estimate dietary requirements for these ostriches (from day 210 to day 240) and results were then extrapolated to estimate requirements for ostriches from dayold to 20 months of age.

MATERIALS AND METHODS

Calculation and statistical analysis of results

Results on requirements for maintenance, utilisation efficiencies, digestibilities of dietary nutrients and carcass characteristics of the experimental group of ostriches used by Cilliers **et al.**, 1994j; 1994k), are presented in Table 1 and Table 2.

Growth results and feed consumption figures of the experimental group of ostriches and their contemporaries were used up to 8 months of age, while values for the remaining period (until 20 months of age), were revealed from growth curves described by Cilliers, Du Preez, Maritz and Hayes, 1994i). Measurements were supplied on a monthly basis (Table 3 to Table 15).

Due to the substantial contributions of gutfill to measured live body weight (LBW) of ostriches (Swart, Siebrits and Hayes, 1993b; Cilliers **et al.,** 1994j), all determinations were done according to empty body weight (EBW). Results on gut fill/LBW ratios by Swart **et al.,** (1993b) were used to derive appropriate estimates for ostriches up to 36 kg LBW, while a constant figure of 80 g/kg LBW (Cilliers **et al.,** 1994j), was used for older birds. The constant value of 80 g/kg is in agreement to measurements conducted at the local abattoir for birds weighing between 90 and 120 kg LBW (Cilliers, unpublished results).

Models for the determination of requirements for maintenance and growth

Requirements were listed on a monthly basis (growth interval), but calculated according to appropriate weights, so that requirements are functions of EBW. Two approaches were used for estimating dietary recommendations for maintenance and growth namely:

1. Method A

ME (TME_n), total protein and amino acids required for maintenance (ME_m, TP_m and AA_m) were estimated according to values calculated by Cilliers **et al.,** (1994j) and listed in Table 2, by using mean period EBW for each growth interval. Mean period EBW was computed by averaging log values of initial and terminal weighings of each growth interval, thus allowing for any deviation from a constant requirement per unit body weight.

ME (TME_n), protein and amino acids required for growth (ME_g, TP_g and AA_g), were computed according to energy, total protein and amino acid contents of complete EBW (incl. feathers), net efficiency of utilisation (kpf) and average daily EBW gain (ADG):

ME_g, MJ/day = $ME_{\text{content of complete EBW}}$, MJ/kg*$kpf^{-1}$*ADG, kg/day [1]

TP_g, MJ/day = $TP_{\text{content of complete EBW}}$, g/kg*$kpf^{-1}$*ADG, kg/day ..... [2]

AA_g, MJ/day = $AA_{\text{content of complete EBW}}$, g/kg TP*$kpf^{-1}$*ADG, kg/day*$TP_{\text{content of complete EBW}}$, g/kg [3]

Dietary levels of ME required to promote growth was estimated by [4]:

Dietary ME, MJ/kg = (ME_m + ME_g), MJ/day / feed consumption, kg/day [4]

Dietary levels of total protein and amino acids were computed according to [5] and [6]:

Dietary TP, g/kg = ((TP_m + TP_g), g/day*DC_{TP}^{-1}) / feed intake, kg/day [5]

Dietary AA, g/kg = ((AA_m + AA_g), g/day*DC_{AA}^{-1}) / feed intake, kg/day [6]

while DC_{TP} and DC_{AA} represented the digestibility and availability coefficients of total protein and the various amino acids respectively.

2. Method B

Emmans (1989), Emmans and Fisher (1986) and Oldham and Emmans (1990) defined effective energy (EE) as dietary ME available for maintenance and growth (ME - heat production) and is calculated according to the digestible protein and lipid and undigestible organic matter proportions in a diet. A growing bird in a thermally neutral environment requires EE for maintenance, protein and lipid retention (Emmans. 1989).

Maintenance requirements EE, (EE_m) is calculated according to potential mature defeathered protein weight, (P_m) and current defeathered protein weight (P) :

EE_m MJ/day = 1.63, MJ*$P_m^{-0.27}$, kg*P, kg [7]

where 1.63 is the EE needed per unit maintenance.

An estimate for mature defeathered protein weight was taken from results presented by Cilliers **et al.,** (1994j), that amounted to 20.66 kg, while current defeathered protein was computed by averaging log values of initial and terminal defeathered protein weights for each growing interval.

Maintenance requirements for protein and amino acids were similarly derived by [8] and [9]:

TP_m kg/day = 0.008, kg*$P_m^{-0.27}$, kg*P, kg [8]

AA_m g/day = 0.008, kg*$P_m^{-0.27}$, kg*P, kg*AAC, g [9]

where 0.008 represents the ideal protein requirement factor for poultry and AAC the amino acid content in defeathered protein (g/kg protein). Protein and amino acids needed for body maintenance was assumed to have identical composition as that of the empty body.

EE required for growth (EE_g) was calculated according to protein and lipid retention rates (ADG*protein content in EBW and ADG*lipid content in EBW) as suggested by Emmans and Fisher (1986):

EE_g for lipid retention = ADG, kg/day * $lipid_{content\ in\ EBW}$, kg/kg * 56 MJ [10]

EE_g for protein retention = ADG, kg/day * $protein_{content\ in\ EBW}$, kg/kg* 60.3 MJ [11]

where 56 MJ and 60.3 MJ are the unit EE needed to retain 1 kg of lipid and protein respectively.

Hence total EE required for growth (EE_g) are the summation of [10] and [11], where protein retention allows for growth in feathers. Emmans (1989), suggested two models for predicting feather protein growth, but these models overestimated the true feather protein contents of ostriches used by Cilliers **et al.**, (1994j). Hence a fixed ratio of 21.48 g/kg for feather weight/EBW, was applied to estimate "as is" feather growth (Cilliers **et al.**, (1994j).

TP_g and AA_g for growth in feathers and defeathered EBW, were computed according to [12] and [13] (Emmans and Fisher, 1986):

$$TP_g = ((TP_{feathers}, g/kg * ADG_{feathers}, kg) + (TP_{defeathered\ EBW}, g/kg * ADG_{defeathered\ EBW}, kg)) * kpf^{-1} * 1.25\ kg \quad [12]$$

$$AA_g, g/day = ((AA_{feathers}, g/kg\ TP * TP_{feathers}, kg * ADG_{feathers}, kg/day) + (AA_{defeathered\ EBW}, g/kg\ TP * TP_{defeathered\ EBW}, kg * ADG_{defeathered\ EBW}, kg/day)) * kpf^{-1} * 1.25\ kg \quad [13]$$

where 1.25 kg represented unit ideal protein requirement.

Dietary levels of EE required to promote growth in protein and lipid tissues, was estimated by [14]:

$$\text{Dietary EE, MJ/kg} = (EE_m + EE_g), MJ/day\ /\ \text{feed consumption, kg/day} \quad [14]$$

Dietary levels of total protein and amino acids were computed according to [15] and [16]:

$$\text{Dietary TP, g/kg} = ((TP_m + TP_g), g/day * DC_{TP}^{-1})\ /\ \text{feed intake, kg/day} \quad [15]$$

$$\text{Dietary AA, g/kg} = ((AA_m + AA_g), g/day * DC_{AA}^{-1})\ /\ \text{feed intake, kg/day} \quad [16]$$

RESULTS

Daily requirements of ME and EE for maintenance and growth and total dietary requirements are given in Table 3. The estimation of EE_g by calculating energy retention as lipid and protein gain, yielded consistently higher values than those obtained for ME. Substantially higher EE_g values were derived in the initial growth stages that were gradually reduced as birds matured. ME_m values were markedly higher that EE_m in the initial growth stages and the differences in requirement declined as bird reached day 270, where after gradually increased EE_m values were determined as opposed to values derived for ME_m. Substantially higher dietary levels of ME were calculated until day 210 when comparable requirements of 10.17 MJ/kg and 9.70 MJ/kg were estimated for ME and EE respectively. Higher values for dietary EE were however calculated from day 330 and the difference between required dietary levels of EE and ME steadily increased.

In estimating requirements for total protein (TP_g) and amino acids (AA_g) to promote potential growth in ostriches, according to method A and method B, yielded comparable values. Inconsistent differences were however observed between the two methods for maintenance requirements of TP and the various AA's. Total dietary requirements for protein, lysine, threonine, methionine, cystine, isoleucine, leucine, arginine, valine, phenylalanine, histidine and tyrosine are given in Table 4 to Table 14. Method A yielded higher dietary requirements for methionine, arginine, histidine and tyrosine, while increased levels were needed for cystine, isoleucine, leucine and valine according to method B.

DISCUSSION

The utilisation of a causal approach to calculate nutrient requirements, involves various biological components for model building that provide information that could accurately predict growth (Fisher, 1980; Gous, 1986). In empirical procedures where a response over a finite period is linked to experimental data, a number of discrete entities are revealed that do not necessarily have any biological meaning (Fisher, 1980, Emmans and Fisher, 1986). Oldhams and Emmans (1990) summarised the aim in assessing nutritional requirements and standards and emphasised the importance of predicting animal performance through nutrition.

In the present study, a combination of empirical and causal approaches were used. Carcass characteristics and nutrient utilisation efficiencies obtained for the 7 month old ostriches (Cilliers **et al.**,1994j), were used to assess requirements for these birds (day 210 to day 240). The same estimates for biological components and utilisation efficiencies were then extrapolated to predict requirements for ostriches in various growth stages. The extrapolation of these results to estimate requirements for other birds has its limitations and a number of assumptions were made:

1. A constant lipid retention rate was assumed which is incorrect according to Emmans and Fisher (1986)
2. A constant rate of feather growth was used while Emmans and Fisher (1986) emphasised that the proportion of total protein retention as feather protein varies widely.
3. Constant protein, energy and amino acid concentration per unit body component was used for birds in various growth intervals.
4. Unit nutrient contents for maintenance were assumed to be similar to that needed for growth.
5. Constant ratios for leg, hide and carcass (EBW - legs - hide - feathers) to EBW were used for birds in various growth intervals.
6. Constant utilisation efficiencies and digestibility values were used for birds in various growth stages

The unrealistic high dietary energy levels for the first 4 month period is the result of overestimating energy retention (hence ME_g and EE_g) due to reduced levels of lipid retention as measured in older birds (Emmans, 1989).

The necessity of a distinction between feather and defeathered EBW gain is also explained by substantial differences in amino acids compositions (Fisher and Scougall, 1982). Results presented by Cilliers **et al.**,(1994h), emphasised that apart from feathers, significant differences in nutrient contents were also observed between hides, carcasses and legs. The rate of growth in these components may also vary, hence indicating the necessity of considering separate gains in these body components.

Calculation of maintenance requirements according to method A, assumed a constant ratio per unit EBW. This is questionable over a long growth period as weights of the liver, kidneys and other organs decrease in relation to EBW with increasing age and EBW (Chwalibog, 1991). Method B however estimate maintenance according to mature and mean period defeathered EBW that should provide estimates that should be more reliable for birds over a long growth period. This is especially true when regular weighings were recorded, thus allowing for any deviations in unit requirements for maintenance (Emmans and Fisher, 1986).

Assuming constant utilisation and digestibility figures for birds in various growth intervals, should carefully be considered. Swart **et al.**,(1993b) observed that energy conversion in ostriches improved as feed conversion rate deteriorates. Scheideler and Angel (1994), measured substantially reduced ME values for a high lipid-fibre diet in young ostriches as opposed to older birds due to impaired digestibilities of dietary fibre and lipid. This was especially true for birds up to 10 weeks, while results obtained for birds from 17 weeks, compared favourably to that obtained for older birds. Similar TME_n values were obtained in mature ostriches and birds of 6 months of age (Cilliers **et al.**,1994g, and comparable digestibilities of protein and amino acids could also be expected.

Requirements obtained in the present study are substantially higher that values derived from theoretical models and graphs calculated by Du Preez (1991). In the study by Du Preez (1990), 6 birds were slaughtered over the entire growth interval (dayold to maturity) to obtain a potential protein growth curve for ostriches. Utilisation efficiencies were however assumed to be similar to that of poultry, explaining the lower values.

For the establishment of accurate dietary requirements for ostriches in various growth intervals, results on potential lipid-free growth curves, lipid retention rates and feather, hide, leg and carcass growth curves are needed. Until these values are defined, results in the present study provide useful information for diet formulation for ostriches, especially for birds from day 150 and older.

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TABLE 1: CARCASS CHARACTERISTICS OF FEATHERS, DEFEATHERED EBW AND COMPLETE EBW (INCL. FEATHERS)

Nutrient content g/kg	Feathers	Defeathered EBW	Complete EBW
Gross Energy, MJ/kg	21.554 ± 0.0865	22.391 ± 1.102	22.854 ± 1.10
Dry Matter, g/kg	824 ± 10.2	340.1 ± 2.865	357.8 ± 3.08
Protein g/kg	713 ± 9.76	193.9 ± 1.459	209.2 ± 1.67
Ether extract, g/kg	8.50 ± 0.355	81.7 ± 2.949	81.9 ± 2.96
THR, g/16 g N	5.41 ± 0.140	3.355 ± 0.044	3.471 ± 0.047
SER, g/16 g N	7.84*	2.938 ± 0.053	3.106 ± 0.053
ALA, g/16 g N	3.95 ± 0.214	5.886 ± 0.098	5.971 ± 0.103
VAL, g/16 g N	8.50 ± 0.0996	4.008 ± 0.049	4.191 ± 0.051
MET, g/16 g N	0.25*	1.898 ± 0.019	1.903 ± 0.019
PHE, g/16 g N	3.47 ± 0.111	4.201 ± 0.120	4.275 ± 0.122
HIS, g/16 g N	0.7*	2.573 ± 0.081	2.588 ± 0.081
LYS, g/16 g N	1.27 ± 0.0378	6.310 ± 0.102	6.337 ± 0.103
ILE, g/16 g N	5.45 ± 0.0601	3.586 ± 0.049	3.695 ± 0.050
TYR, g/16 g N	3.15 ± 0.0293	2.883 ± 0.066	2.951 ± 0.067
ARG, g/16 g N	5.54 ± 0.279	6.687 ± 0.242	6.806 ± 0.248
CYS, g/16 g N	5.64 ± 0.106	0.855 ± 0.021	0.976 ± 0.024
LEU, g/16 g N	8.68 ± 0.0916	6.338 ± 0.074	6.525 ± 0.076

Results from Cilliers **et al.**, (1994j)

* Results from Du Preez (1991)

TABLE 2: DIGESTIBILITIES, MAINTENANCE REQUIREMENTS, RETENTION RATES AND UTILISATION EFFICIENCIES OF VARIOUS NUTRIENTS IN OSTRICHES

Nutrient content g/kg	Digestibility coefficients	mg/EBW, kg/day Maintenance requirement	g/Day Retention rates	Net efficiency of utilisation
Energy, ME	11.25 ± 0.0724	425 ± 2.37[a]	8.2 ± 0.372*	0.414 ± 0.00644
Energy, EE	8.20 ± 0.320	311 ± 3.48[a]		0.568 ± 0.0088
Protein	0.646 ± 0.0114	678 ± 27.1[b]	75 ± 3.06	0.672 ± 0.0152
Lipid	0.870 ± 0.00411		33 ± 3.25	
THR	0.831 ± 0.00263	57 ± 2.39	3.904 ± 0.137	0.710 ± 0.0199
SER	0.849 ± 0.00272	53 ± 2.18	3.655 ± 0.104	0.615 ± 0.0344
ALA	0.937 ± 0.00410	86 ± 3.60	6.654 ± 0.209	0.968 ± 0.0537
VAL	0.862 ± 0.00282	65 ± 2.69	4.697 ± 0.178	0.702 ± 0.0369
MET	0.816 ± 0.00300	38 ± 1.57	2.124 ± 0.0673	0.780 ± 0.0197
PHE	0.809 ± 0.00527	68 ± 2.81	4.830 ± 0.138	0.654 ± 0.0241
HIS	0.854 ± 0.00362	47 ± 1.97	2.896 ± 0.0883	0.877 ± 0.0408
LYS	0.832 ± 0.00386	91 ± 3.79	7.102 ± 0.217	0.733 ± 0.0163
ILE	0.829 ± 0.00239	60 ± 2.51	4.126 ± 0.136	0.682 ± 0.0386
TYR	0.816 ± 0.0374	51 ± 2.14	3.299 ± 0.104	0.904 ± 0.0461
ARG	0.780 ± 0.00609	96 ± 3.98	7.700 ± 0.221	0.948 ± 0.0252
CYS	0.806 ± 0.0188	21 ± 0.884	1.212 ± 0.0585	0.569 ± 0.0152
LEU	0.859 ± 0.00206	91 ± 3.81	7.244 ± 0.266	0.569 ± 0.0263

Maintenance requirements are requirements of digestible nutrients

* Unit for energy retention rate, MJ/day

[a] Unit for EE and ME requirements, kJ/EBW, $kg^{0.75}$/day

[b] Unit for protein requirements, mg/EBW, $kg^{0.75}$/kg

TABLE 3: ESTIMATION OF METABOLISABLE AND EFFECTIVE ENERGY REQUIREMENTS FOR MAINTENANCE (ME_m, EE_m) AND GROWTH (ME_g, EE_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	MJ/DAY TOTAL ENERGY GAIN	MJ/DAY REQUIRED ME INTAKE FOR GROWTH	MJ/DAY REQUIRED ME INTAKE FOR MAINTEN.	MJ/DAY TOTAL REQUIRED ME INTAKE	MJ/KG DIETARY ME LEVELS	MJ/DAY ENERGY AS PROTEIN RETENTION	MJ/DAY ENERGY AS LIPID RETENTION	MJ/DAY REQUIRED TOTAL EE INTAKE FOR GROWTH	MJ/DAY REQUIRED EE INTAKE FOR MAINT.	MJ/DAY TOTAL REQUIRED EE INTAKE	MJ/KG DIETARY EE LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	2.400	2.672	0.673	3.345	13.65	1.32	0.482	2.983	0.256	3.241	13.23
60	11.0	9.1	6.6	0.233	0.49	5.333	5.938	1.757	7.695	15.70	2.94	1.070	6.629	0.926	6.864	14.01
90	19.5	16.6	14.6	0.283	0.75	6.475	7.211	3.182	10.393	13.86	3.57	1.299	8.050	2.045	9.255	12.34
120	28.5	25.0	23.6	0.300	0.91	6.856	7.635	4.547	12.182	13.39	3.78	1.376	8.524	3.291	10.926	12.01
150	39.5	36.2	33.6	0.367	1.35	8.380	9.332	5.925	15.257	11.30	4.62	1.682	10.418	4.684	14.016	10.38
180	52.1	47.9	45.4	0.420	1.65	9.599	10.689	7.429	18.118	10.98	5.29	1.926	11.933	6.333	17.022	10.32
210	63.4	58.3	57.5	0.375	1.81	8.570	9.544	8.869	18.412	10.17	4.73	1.720	10.654	8.020	17.564	9.70
240	73.3	67.4	68.1	0.330	1.9	7.542	8.398	10.077	18.476	9.72	4.16	1.514	9.376	9.510	17.908	9.43
270	82.4	75.8	77.6	0.305	1.95	6.970	7.762	11.122	18.884	9.68	3.84	1.399	8.666	10.846	18.608	9.54
300	91.0	83.7	86.5	0.287	2.0	6.551	7.296	12.064	19.360	9.68	3.61	1.315	8.145	12.089	19.385	9.69
330	96.3	88.6	93.6	0.177	2.4	4.038	4.496	12.791	17.287	7.20	2.23	0.810	5.019	13.069	17.565	7.32
360	99.9	91.9	98.0	0.120	2.45	2.742	3.054	13.246	16.300	6.65	1.51	0.550	3.409	13.693	16.747	6.84
390	103.5	95.2	101.6	0.120	2.5	2.742	3.054	13.609	16.663	6.67	1.51	0.550	3.409	14.196	17.250	6.90
420	107.0	98.4	105.2	0.117	2.5	2.666	2.969	13.964	16.933	6.77	1.47	0.535	3.315	14.692	17.661	7.06
450	110.0	101.2	108.4	0.100	2.5	2.285	2.545	14.287	16.832	6.73	1.26	0.459	2.841	15.146	17.691	7.08
480	112.3	103.3	111.1	0.077	2.5	1.752	1.951	14.548	16.499	6.60	0.97	0.352	2.178	15.516	17.468	6.99
510	114.2	105.1	113.2	0.063	2.5	1.447	1.612	14.754	16.366	6.55	0.80	0.290	1.799	15.810	17.422	6.97
540	116.0	106.7	115.0	0.060	2.5	1.371	1.527	14.934	16.461	6.58	0.76	0.275	1.705	16.068	17.595	7.04
570	118.6	109.1	117.2	0.087	2.5	1.981	2.206	15.148	17.353	6.94	1.09	0.397	2.462	16.375	18.580	7.43
600	120.3	110.7	119.4	0.057	2.5	1.295	1.442	15.356	16.798	6.72	0.71	0.260	1.610	16.676	18.118	7.25

METHOD A: Total energy retention measured in EBW. Maintenance was calculated according to 0.678 g/kg EBW.

METHOD B: Energy retention as lipid and protein retention was seperately calculated. Requirements for maintenance were estimated according to mature defeathered protein weight and mean period defeathered protein weight.

TABLE 4: ESTIMATION OF THE PROTEIN REQUIREMENTS FOR MAINTENANCE (TP_m) AND GROWTH (TP_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL PROTEIN GAIN	G/DAY REQUIRED PROTEIN INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE PROTEIN INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED PROTEIN INTAKE	G/KG DIETARY PROTEIN LEVELS	G/DAY DEFEATHERED BODY PROTEIN GAIN	G/DAY FEATHER PROTEIN GAIN	G/DAY REQUIRED DIGESTIBLE PROTEIN INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE PROTEIN INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED PROTEIN INTAKE	G/KG DIETARY PROTEIN LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	21.95	32.66	1.25	52.48	214.2	20.37	1.61	32.71	1.26	52.58	214.6
60	11.0	9.1	6.6	0.233	0.49	48.77	72.57	4.50	119.29	243.5	45.27	3.57	72.68	4.54	119.54	244.0
90	19.5	16.6	14.6	0.283	0.75	59.22	88.12	9.93	151.78	202.4	54.97	4.34	88.25	10.04	152.15	202.9
120	28.5	25.0	23.6	0.300	0.91	62.70	93.30	15.98	169.17	185.9	58.20	4.59	93.44	16.15	169.65	186.4
150	39.5	36.2	33.6	0.367	1.35	76.63	114.04	22.75	211.74	156.8	71.13	5.62	114.21	22.99	212.38	157.3
180	52.1	47.9	45.4	0.420	1.65	87.78	130.63	30.76	249.81	151.4	81.48	6.43	130.82	31.08	250.63	151.9
210	63.4	58.3	57.5	0.375	1.81	78.38	116.63	38.95	240.83	133.1	72.75	5.74	116.81	39.36	241.75	133.6
240	73.3	67.4	68.1	0.330	1.9	68.97	102.63	46.19	230.37	121.2	64.02	5.05	102.79	46.67	231.37	121.8
270	82.4	75.8	77.6	0.305	1.95	63.75	94.86	52.67	228.37	117.1	59.17	4.67	95.00	53.23	229.46	117.7
300	91.0	83.7	86.5	0.287	2.0	59.91	89.16	58.71	228.89	114.4	55.61	4.39	89.29	59.33	230.07	115.0
330	96.3	88.6	93.6	0.177	2.4	36.92	54.95	63.47	183.30	76.4	34.27	2.71	55.03	64.14	184.47	76.9
360	99.9	91.9	98.0	0.120	2.45	25.08	37.32	66.50	160.71	65.6	23.28	1.84	37.38	67.21	161.89	66.1
390	103.5	95.2	101.6	0.120	2.5	25.08	37.32	68.94	164.49	65.8	23.28	1.84	37.38	69.67	165.71	66.3
420	107.0	98.4	105.2	0.117	2.5	24.38	36.28	71.35	166.61	66.6	22.63	1.79	36.34	72.11	167.87	67.1
450	110.0	101.2	108.4	0.100	2.5	20.90	31.10	73.56	162.00	64.8	19.40	1.53	31.15	74.34	163.29	65.3
480	112.3	103.3	111.1	0.077	2.5	16.02	23.84	75.36	153.56	61.4	14.87	1.17	23.88	76.15	154.85	61.9
510	114.2	105.1	113.2	0.063	2.5	13.24	19.70	76.78	149.34	59.7	12.29	0.97	19.73	77.59	150.65	60.3
540	116.0	106.7	115.0	0.060	2.5	12.54	18.66	78.04	149.68	59.9	11.64	0.92	18.69	78.86	151.01	60.4
570	118.6	109.1	117.2	0.087	2.5	18.11	26.95	79.52	164.82	65.9	16.81	1.33	27.00	80.37	166.20	66.5
600	120.3	110.7	119.4	0.057	2.5	11.84	17.62	80.99	152.64	61.1	10.99	0.87	17.65	81.84	154.01	61.6

METHOD A: Combined protein retention was used and requirements for maintenance were calculated to according 0.678 g/kg EBW.

METHOD B: Protein retention in feathers and body protein was calculated seperately and requirements for maintenance were calculated using mature defeathered protein weight and mean defeathered protein weight.

TABLE 5: ESTIMATION OF THE LYSINE REQUIREMENTS FOR MAINTENANCE (LYS_m) AND GROWTH (LYS_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL LYSINE GAIN	G/DAY REQUIRED LYSINE INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE LYSINE INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED LYSINE INTAKE	G/KG DIETARY LYSINE LEVELS	G/DAY DEFEATHERED BODY LYSINE GAIN	G/DAY FEATHER LYSINE GAIN	G/DAY REQUIRED LYSINE INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE LYSINE INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED LYSINE INTAKE	G/KG DIETARY LYSINE LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	1.39	1.90	0.17	2.48	10.2	1.29	0.02	1.79	0.16	2.34	9.6
60	11.0	9.1	6.6	0.233	0.49	3.10	4.23	0.60	5.80	11.8	2.86	0.05	3.97	0.59	5.48	11.2
90	19.5	16.6	14.6	0.283	0.75	3.76	5.13	1.33	7.77	10.4	3.48	0.06	4.82	1.31	7.36	9.8
120	28.5	25.0	23.6	0.300	0.91	3.98	5.44	2.15	9.11	10.0	3.68	0.06	5.10	2.10	8.66	9.5
150	39.5	36.2	33.6	0.367	1.35	4.87	6.64	3.05	11.65	8.6	4.50	0.07	6.24	2.99	11.09	8.2
180	52.1	47.9	45.4	0.420	1.65	5.58	7.61	4.13	14.01	8.5	5.15	0.08	7.14	4.05	13.45	8.2
210	63.4	58.3	57.5	0.375	1.81	4.98	6.79	5.23	14.44	8.0	4.60	0.07	6.38	5.12	13.82	7.6
240	73.3	67.4	68.1	0.330	1.9	4.38	5.98	6.20	14.63	7.7	4.05	0.06	5.61	6.08	14.05	7.4
270	82.4	75.8	77.6	0.305	1.95	4.05	5.53	7.07	15.13	7.8	3.74	0.06	5.19	6.93	14.56	7.5
300	91.0	83.7	86.5	0.287	2.0	3.81	5.19	7.88	15.71	7.9	3.52	0.06	4.88	7.72	15.14	7.6
330	96.3	88.6	93.6	0.177	2.4	2.35	3.20	8.52	14.08	5.9	2.17	0.03	3.00	8.35	13.65	5.7
360	99.9	91.9	98.0	0.120	2.45	1.59	2.17	8.93	13.34	5.4	1.47	0.02	2.04	8.75	12.97	5.3
390	103.5	95.2	101.6	0.120	2.5	1.59	2.17	9.25	13.73	5.5	1.47	0.02	2.04	9.07	13.35	5.3
420	107.0	98.4	105.2	0.117	2.5	1.55	2.11	9.58	14.05	5.6	1.43	0.02	1.98	9.39	13.67	5.5
450	110.0	101.2	108.4	0.100	2.5	1.33	1.81	9.87	14.04	5.6	1.23	0.02	1.70	9.68	13.67	5.5
480	112.3	103.3	111.1	0.077	2.5	1.02	1.39	10.11	13.82	5.5	0.94	0.01	1.30	9.91	13.48	5.4
510	114.2	105.1	113.2	0.063	2.5	0.84	1.15	10.31	13.76	5.5	0.78	0.01	1.08	10.10	13.43	5.4
540	116.0	106.7	115.0	0.060	2.5	0.80	1.09	10.47	13.89	5.6	0.74	0.01	1.02	10.27	13.56	5.4
570	118.6	109.1	117.2	0.087	2.5	1.15	1.57	10.67	14.71	5.9	1.06	0.02	1.47	10.46	14.34	5.7
600	120.3	110.7	119.4	0.057	2.5	0.75	1.03	10.87	14.29	5.7	0.70	0.01	0.96	10.65	13.96	5.6

METHOD A: Combined Lysine retention was used and requirements for maintenance were calculated to according 0.091 g/kg EBW.

METHOD B: Lysine retention in feathers and body lysine was calculated seperately and requirements for maintenance were calculated using mature defeathered lysine weight and mean defeathered lysine weight.

TABLE 6: ESTIMATION OF THE THREONINE REQUIREMENTS FOR MAINTENANCE (THR_m) AND GROWTH (THR_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL THR GAIN	G/DAY REQUIRED THR INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE THR INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED THR INTAKE	G/KG DIETARY THR LEVELS	G/DAY DEFEATHERED BODY THR GAIN	G/DAY FEATHER THR GAIN	G/DAY REQUIRED THR INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE THR INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED THR INTAKE	G/KG DIETARY THR LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	0.76	1.08	0.11	1.42	5.8	0.69	0.09	1.09	0.10	1.43	5.8
60	11.0	9.1	6.6	0.233	0.49	1.70	2.39	0.38	3.33	6.8	1.52	0.19	2.42	0.36	3.34	6.8
90	19.5	16.6	14.6	0.283	0.75	2.06	2.90	0.83	4.49	6.0	1.85	0.23	2.93	0.79	4.48	6.0
120	28.5	25.0	23.6	0.300	0.91	2.18	3.07	1.34	5.31	5.8	1.96	0.25	3.11	1.27	5.26	5.8
150	39.5	36.2	33.6	0.367	1.35	2.67	3.76	1.91	6.82	5.1	2.39	0.30	3.80	1.80	6.74	5.0
180	52.1	47.9	45.4	0.420	1.65	3.06	4.30	2.59	8.29	5.0	2.74	0.35	4.35	2.44	8.17	5.0
210	63.4	58.3	57.5	0.375	1.81	2.73	3.84	3.27	8.56	4.7	2.45	0.31	3.88	3.09	8.39	4.6
240	73.3	67.4	68.1	0.330	1.9	2.40	3.38	3.88	8.74	4.6	2.15	0.27	3.42	3.66	8.52	4.5
270	82.4	75.8	77.6	0.305	1.95	2.22	3.13	4.43	9.09	4.7	1.99	0.25	3.16	4.17	8.83	4.5
300	91.0	83.7	86.5	0.287	2.0	2.09	2.94	4.94	9.47	4.7	1.87	0.24	2.97	4.65	9.17	4.6
330	96.3	88.6	93.6	0.177	2.4	1.29	1.81	5.34	8.60	3.6	1.15	0.15	1.83	5.03	8.25	3.4
360	99.9	91.9	98.0	0.120	2.45	0.87	1.23	5.59	8.20	3.3	0.78	0.10	1.24	5.27	7.84	3.2
390	103.5	95.2	101.6	0.120	2.5	0.87	1.23	5.80	8.45	3.4	0.78	0.10	1.24	5.46	8.07	3.2
420	107.0	98.4	105.2	0.117	2.5	0.85	1.20	6.00	8.65	3.5	0.76	0.10	1.21	5.65	8.26	3.3
450	110.0	101.2	108.4	0.100	2.5	0.73	1.02	6.18	8.67	3.5	0.65	0.08	1.04	5.83	8.26	3.3
480	112.3	103.3	111.1	0.077	2.5	0.56	0.79	6.34	8.56	3.4	0.50	0.06	0.79	5.97	8.14	3.3
510	114.2	105.1	113.2	0.063	2.5	0.46	0.65	6.46	8.54	3.4	0.41	0.05	0.66	6.08	8.11	3.2
540	116.0	106.7	115.0	0.060	2.5	0.44	0.61	6.56	8.63	3.5	0.39	0.05	0.62	6.18	8.19	3.3
570	118.6	109.1	117.2	0.087	2.5	0.63	0.89	6.69	9.11	3.6	0.57	0.07	0.90	6.30	8.66	3.5
600	120.3	110.7	119.4	0.057	2.5	0.41	0.58	6.81	8.89	3.6	0.37	0.05	0.59	6.42	8.43	3.4

METHOD A: Combined Threonine retention was used and requirements for maintenance were calculated to according 0.057 g/kg EBW.

METHOD B: Threonine retention in feathers and body threonine was calculated seperately and requirements for maintenance were calculated using mature defeathered threonine weight and mean defeathered threonine weight.

TABLE 7: ESTIMATION OF THE METHIONINE REQUIREMENTS FOR MAINTENANCE (MET_m) AND GROWTH (MET_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL MET GAIN	G/DAY REQUIRED MET INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE MET INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED MET INTAKE	G/KG DIETARY MET LEVELS	G/DAY DEFEATHERED BODY MET GAIN	G/DAY FEATHER MET GAIN	G/DAY REQUIRED MET INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE MET INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED MET INTAKE	G/KG DIETARY MET LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	0.42	0.54	0.07	0.74	3.0	0.39	0.004	0.50	0.05	0.68	2.8
60	11.0	9.1	6.6	0.233	0.49	0.93	1.19	0.25	1.77	3.6	0.86	0.009	1.12	0.19	1.60	3.3
90	19.5	16.6	14.6	0.283	0.75	1.13	1.45	0.56	2.45	3.3	1.05	0.011	1.36	0.42	2.18	2.9
120	28.5	25.0	23.6	0.300	0.91	1.20	1.53	0.90	2.97	3.3	1.11	0.012	1.44	0.68	2.59	2.8
150	39.5	36.2	33.6	0.367	1.35	1.46	1.87	1.27	3.86	2.9	1.35	0.015	1.75	0.97	3.33	2.5
180	52.1	47.9	45.4	0.420	1.65	1.67	2.15	1.72	4.74	2.9	1.55	0.017	2.01	1.31	4.06	2.5
210	63.4	58.3	57.5	0.375	1.81	1.50	1.92	2.18	5.02	2.8	1.38	0.015	1.79	1.65	4.23	2.3
240	73.3	67.4	68.1	0.330	1.9	1.32	1.69	2.59	5.24	2.8	1.22	0.013	1.58	1.96	4.34	2.3
270	82.4	75.8	77.6	0.305	1.95	1.22	1.56	2.95	5.52	2.8	1.13	0.012	1.46	2.24	4.53	2.3
300	91.0	83.7	86.5	0.287	2.0	1.14	1.47	3.29	5.82	2.9	1.06	0.011	1.37	2.49	4.74	2.4
330	96.3	88.6	93.6	0.177	2.4	0.70	0.90	3.56	5.46	2.3	0.65	0.007	0.85	2.69	4.34	1.8
360	99.9	91.9	98.0	0.120	2.45	0.48	0.61	3.73	5.31	2.2	0.44	0.005	0.57	2.82	4.16	1.7
390	103.5	95.2	101.6	0.120	2.5	0.48	0.61	3.86	5.48	2.2	0.44	0.005	0.57	2.93	4.29	1.7
420	107.0	98.4	105.2	0.117	2.5	0.47	0.60	4.00	5.63	2.3	0.43	0.005	0.56	3.03	4.40	1.8
450	110.0	101.2	108.4	0.100	2.5	0.40	0.51	4.12	5.67	2.3	0.37	0.004	0.48	3.12	4.41	1.8
480	112.3	103.3	111.1	0.077	2.5	0.31	0.39	4.22	5.65	2.3	0.28	0.003	0.37	3.20	4.37	1.7
510	114.2	105.1	113.2	0.063	2.5	0.25	0.32	4.30	5.67	2.3	0.23	0.003	0.30	3.26	4.37	1.7
540	116.0	106.7	115.0	0.060	2.5	0.24	0.31	4.37	5.73	2.3	0.22	0.002	0.29	3.31	4.41	1.8
570	118.6	109.1	117.2	0.087	2.5	0.35	0.44	4.46	6.00	2.4	0.32	0.003	0.41	3.38	4.65	1.9
600	120.3	110.7	119.4	0.057	2.5	0.23	0.29	4.54	5.91	2.4	0.21	0.002	0.27	3.44	4.55	1.8

METHOD A: Combined methionine retention was used and requirements for maintenance were calculated to according 0.038 g/kg EBW.

METHOD B: Methionine retention in feathers and body methionine was calculated seperately and requirements for maintenance were calculated using mature defeathered methionine weight and mean defeathered methionine weight.

TABLE 8: ESTIMATION OF THE CYSTINE REQUIREMENTS FOR MAINTENANCE (CYS_m) AND GROWTH (CYS_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL CYS GAIN	G/DAY REQUIRED CYS INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE CYS INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED CYS INTAKE	G/KG DIETARY CYS LEVELS	G/DAY DEFEATHERED BODY CYS GAIN	G/DAY FEATHER CYS GAIN	G/DAY REQUIRED CYS INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE CYS INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED CYS INTAKE	G/KG DIETARY CYS LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	0.21	0.38	0.04	0.52	2.11	0.17	0.09	0.47	0.03	0.62	2.5
60	11.0	9.1	6.6	0.233	0.49	0.48	0.84	1.14	1.21	2.48	0.39	0.20	1.04	0.12	1.44	2.9
90	19.5	16.6	14.6	0.283	0.75	0.58	1.02	0.31	1.65	2.19	0.47	0.24	1.26	0.28	1.90	2.5
120	28.5	25.0	23.6	0.300	0.91	0.61	1.08	0.50	1.95	2.15	0.50	0.26	1.33	0.44	2.20	2.4
150	39.5	36.2	33.6	0.367	1.35	0.75	1.32	0.70	2.51	1.86	0.61	0.32	1.63	0.63	2.80	2.1
180	52.1	47.9	45.4	0.420	1.65	0.86	1.51	0.95	3.06	1.85	0.70	0.36	1.86	0.85	3.37	2.0
210	63.4	58.3	57.5	0.375	1.81	0.77	1.35	1.21	3.17	1.75	0.62	0.32	1.66	1.08	3.41	1.9
240	73.3	67.4	68.1	0.330	1.9	0.68	1.19	1.43	3.25	1.71	0.55	0.28	1.47	1.28	3.41	1.8
270	82.4	75.8	77.6	0.305	1.95	0.62	1.10	1.63	3.38	1.74	0.51	0.26	1.35	1.46	3.49	1.8
300	91.0	83.7	86.5	0.287	2.0	0.59	1.03	1.82	3.54	1.77	0.48	0.25	1.27	1.63	3.60	1.8
330	96.3	88.6	93.6	0.177	2.4	0.36	0.64	1.97	3.23	1.34	0.29	0.15	0.78	1.76	3.16	1.3
360	99.9	91.9	98.0	0.120	2.45	0.25	0.43	2.06	3.09	1.26	0.20	0.10	0.53	1.85	2.95	1.2
390	103.5	95.2	101.6	0.120	2.5	0.25	0.43	2.14	3.18	1.27	0.20	0.10	0.53	1.91	3.04	1.2
420	107.0	98.4	105.2	0.117	2.5	0.24	0.42	2.21	3.26	1.30	0.19	0.10	0.52	1.98	3.10	1.2
450	110.0	101.2	108.4	0.100	2.5	0.20	0.36	2.28	3.27	1.31	0.17	0.09	0.44	2.04	3.08	1.2
480	112.3	103.3	111.1	0.077	2.5	0.16	0.28	2.33	3.24	1.30	0.13	0.07	0.34	2.09	3.02	1.2
510	114.2	105.1	113.2	0.063	2.5	0.13	0.23	2.38	3.23	1.29	0.11	0.05	0.28	2.13	2.99	1.2
540	116.0	106.7	115.0	0.060	2.5	0.12	0.22	2.42	3.27	1.31	0.10	0.05	0.27	2.17	3.02	1.2
570	118.6	109.1	117.2	0.087	2.5	0.18	0.31	2.46	3.44	1.38	0.14	0.07	0.38	2.21	3.22	1.3
600	120.3	110.7	119.4	0.057	2.5	0.12	0.20	2.51	3.36	1.35	0.09	0.05	0.25	2.25	3.10	1.2

METHOD A: Combined cystine retention was used and requirements for maintenance were calculated to according 0.021 g/kg EBW.

METHOD B: Cystine retention in feathers and body cystine was calculated seperately and requirements for maintenance were calculated using mature defeathered cystine weight and mean defeathered cystine weight.

TABLE 9: ESTIMATION OF THE ISOLEUCINE REQUIREMENTS FOR MAINTENANCE (ILE_m) AND GROWTH (ILE_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL ILE GAIN	G/DAY REQUIRED ILE INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE ILE INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED ILE INTAKE	G/KG DIETARY ILE LEVELS	G/DAY DEFEATHERED BODY ILE GAIN	G/DAY FEATHER ILE GAIN	G/DAY REQUIRED ILE INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE ILE INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED ILE INTAKE	G/KG DIETARY ILE LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	0.81	1.19	0.11	1.57	6.4	0.73	0.08	1.19	0.12	1.92	7.8
60	11.0	9.1	6.6	0.233	0.49	1.81	2.65	0.40	3.67	7.5	1.63	0.18	2.65	0.43	4.51	9.2
90	19.5	16.6	14.6	0.283	0.75	2.19	3.22	0.88	4.94	6.6	1.98	0.21	3.22	0.94	6.10	8.1
120	28.5	25.0	23.6	0.300	0.91	2.32	3.41	1.41	5.81	6.4	2.09	0.23	3.41	1.52	7.22	7.9
150	39.5	36.2	33.6	0.367	1.35	2.84	4.16	2.01	7.45	5.5	2.56	0.28	4.17	2.16	9.27	6.9
180	52.1	47.9	45.4	0.420	1.65	3.25	4.77	2.72	9.03	5.5	2.93	0.32	4.77	2.92	11.28	6.8
210	63.4	58.3	57.5	0.375	1.81	2.90	4.26	3.45	9.29	5.1	2.62	0.29	4.26	3.70	11.67	6.4
240	73.3	67.4	68.1	0.330	1.9	2.56	3.75	4.09	9.45	5.0	2.30	0.25	3.75	4.38	11.92	6.3
270	82.4	75.8	77.6	0.305	1.95	2.36	3.46	4.66	9.80	5.0	2.13	0.23	3.47	5.00	12.41	6.4
300	91.0	83.7	86.5	0.287	2.0	2.22	3.25	5.20	10.19	5.1	2.00	0.22	3.26	5.57	12.94	6.5
330	96.3	88.6	93.6	0.177	2.4	1.37	2.01	5.62	9.19	3.8	1.23	0.13	2.01	6.02	11.77	4.9
360	99.9	91.9	98.0	0.120	2.45	0.93	1.36	5.89	8.74	3.6	0.84	0.09	1.36	6.31	11.25	4.6
390	103.5	95.2	101.6	0.120	2.5	0.93	1.36	6.10	9.00	3.6	0.84	0.09	1.36	6.54	11.59	4.6
420	107.0	98.4	105.2	0.117	2.5	0.90	1.32	6.31	9.21	3.7	0.81	0.09	1.33	6.77	11.87	4.7
450	110.0	101.2	108.4	0.100	2.5	0.77	1.14	6.51	9.22	3.7	0.70	0.07	1.14	6.98	11.90	4.8
480	112.3	103.3	111.1	0.077	2.5	0.59	0.87	6.67	9.09	3.6	0.53	0.06	0.87	7.15	11.76	4.7
510	114.2	105.1	113.2	0.063	2.5	0.49	0.72	6.79	9.06	3.6	0.44	0.05	0.72	7.29	11.74	4.7
540	116.0	106.7	115.0	0.060	2.5	0.46	0.68	6.91	9.15	3.7	0.42	0.05	0.68	7.40	11.86	4.7
570	118.6	109.1	117.2	0.087	2.5	0.67	0.98	7.04	9.67	3.9	0.60	0.07	0.98	7.55	12.51	5.0
600	120.3	110.7	119.4	0.057	2.5	0.44	0.64	7.17	9.42	3.8	0.40	0.04	0.64	7.68	12.21	4.9

METHOD A: Combined isoleucine retention were used and requirements for maintenance were calculated according to 0.060 g/kg EBW.

METHOD B: Isoleucine retention in feathers and body isoleucine was calculated seperately and requirements for maintenance were calculated using mature defeathered isoleusine weight and mean defeathered isoleucine weight.

TABLE 10: ESTIMATION OF THE LEUCINE REQUIREMENTS FOR MAINTENANCE (LEU_m) AND GROWTH (LEU_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL LEU GAIN	G/DAY REQUIRED LEU INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE LEU INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED LEU INTAKE	G/KG DIETARY LEU LEVELS	G/DAY DEFEATHERED BODY LEU GAIN	G/DAY FEATHER LEU GAIN	G/DAY REQUIRED LEU INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE LEU INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED LEU INTAKE	G/KG DIETARY LEU LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	1.44	2.52	0.17	3.13	12.79	1.29	0.14	2.52	0.22	3.19	13.0
60	11.0	9.1	6.6	0.233	0.49	3.19	5.61	0.60	7.23	14.76	2.88	0.31	5.60	0.80	7.46	15.2
90	19.5	16.6	14.6	0.283	0.75	3.87	6.81	1.33	9.48	12.64	3.49	0.38	6.80	1.78	9.99	13.3
120	28.5	25.0	23.6	0.300	0.91	4.10	7.21	2.15	10.89	11.97	3.70	0.40	7.20	2.86	11.71	12.9
150	39.5	36.2	33.6	0.367	1.35	5.01	8.81	3.05	13.81	10.23	4.52	0.49	8.80	4.07	14.98	11.1
180	52.1	47.9	45.4	0.420	1.65	5.74	10.09	4.13	16.56	10.03	5.18	0.56	10.08	5.50	18.14	11.0
210	63.4	58.3	57.5	0.375	1.81	5.13	9.01	5.23	16.58	9.16	4.62	0.50	9.00	6.97	18.59	10.3
240	73.3	67.4	68.1	0.330	1.9	4.51	7.93	6.20	16.45	8.66	4.07	0.44	7.92	8.26	18.84	9.9
270	82.4	75.8	77.6	0.305	1.95	4.17	7.33	7.07	16.76	8.60	3.76	0.41	7.32	9.42	19.49	10.0
300	91.0	83.7	86.5	0.287	2.0	3.92	6.89	7.88	17.19	8.60	3.53	0.38	6.88	10.50	20.24	10.1
330	96.3	88.6	93.6	0.177	2.4	2.42	4.25	8.52	14.86	6.19	2.18	0.23	4.24	11.35	18.15	7.6
360	99.9	91.9	98.0	0.120	2.45	1.64	2.88	8.93	13.75	5.61	1.48	0.16	2.88	11.90	17.20	7.0
390	103.5	95.2	101.6	0.120	2.5	1.64	2.88	9.25	14.13	5.65	1.48	0.16	2.88	12.33	17.71	7.1
420	107.0	98.4	105.2	0.117	2.5	1.60	2.80	9.58	14.41	5.76	1.44	0.16	2.80	12.76	18.21	7.2
450	110.0	101.2	108.4	0.100	2.5	1.37	2.40	9.87	14.29	5.72	1.23	0.13	2.40	13.16	18.11	7.2
480	112.3	103.3	111.1	0.077	2.5	1.05	1.84	10.11	13.92	5.57	0.95	0.10	1.84	13.48	17.84	7.1
510	114.2	105.1	113.2	0.063	2.5	0.87	1.52	10.31	13.77	5.51	0.78	0.08	1.52	13.74	17.76	7.1
540	116.0	106.7	115.0	0.060	2.5	0.82	1.44	10.47	13.87	5.55	0.74	0.08	1.44	13.96	17.93	7.2
570	118.6	109.1	117.2	0.087	2.5	1.19	2.08	10.67	14.85	5.94	1.07	0.12	2.08	14.23	18.98	7.6
600	120.3	110.7	119.4	0.057	2.5	0.77	1.36	10.87	14.24	5.70	0.70	0.08	1.36	14.49	18.45	7.4

METHOD A: Combined leucine retention was used and requirements for maintenance were calculated to according 0.091 g/kg EBW.

METHOD B: Leucine retention in feathers and body leucine was calculated seperately and requirements for maintenance were calculated using mature defeathered leucine weight and mean defeathered leucine weight.

TABLE 11: ESTIMATION OF THE ARGININE REQUIREMENTS FOR MAINTENANCE (ARG_m) AND GROWTH (ARG_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL ARG GAIN	G/DAY REQUIRED ARG INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE ARG INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED ARG INTAKE	G/KG DIETARY ARG LEVELS	G/DAY DEFEATHERED BODY ARG GAIN	G/DAY FEATHER ARG GAIN	G/DAY REQUIRED ARG INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE ARG INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED ARG INTAKE	G/KG DIETARY ARG LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	1.50	1.52	0.18	2.17	8.9	1.37	0.089	1.53	0.15	2.16	8.8
60	11.0	9.1	6.6	0.233	0.49	3.33	3.38	0.64	5.15	10.5	3.03	0.198	3.41	0.55	5.07	10.4
90	19.5	16.6	14.6	0.283	0.75	4.04	4.11	1.41	7.06	9.4	3.68	0.240	4.14	1.21	6.86	9.1
120	28.5	25.0	23.6	0.300	0.91	4.28	4.35	2.26	8.47	9.3	3.90	0.255	4.38	1.95	8.12	8.9
150	39.5	36.2	33.6	0.367	1.35	5.23	5.31	3.22	10.94	8.1	4.77	0.311	5.36	2.77	10.42	7.7
180	52.1	47.9	45.4	0.420	1.65	5.99	6.09	4.36	13.38	8.1	5.46	0.356	6.14	3.75	12.67	7.7
210	63.4	58.3	57.5	0.375	1.81	5.35	5.43	5.52	14.03	7.8	4.88	0.318	5.48	4.74	13.11	7.2
240	73.3	67.4	68.1	0.330	1.9	4.71	4.78	6.54	14.51	7.6	4.29	0.280	4.82	5.63	13.39	7.0
270	82.4	75.8	77.6	0.305	1.95	4.35	4.42	7.46	15.23	7.8	3.97	0.259	4.46	6.42	13.94	7.1
300	91.0	83.7	86.5	0.287	2.0	4.09	4.15	8.31	15.98	8.0	3.73	0.243	4.19	7.15	14.54	7.3
330	96.3	88.6	93.6	0.177	2.4	2.52	2.56	8.99	14.80	6.2	2.30	0.150	2.58	7.73	13.22	5.5
360	99.9	91.9	98.0	0.120	2.45	1.71	1.74	9.42	14.30	5.8	1.56	0.102	1.75	8.10	12.63	5.2
390	103.5	95.2	101.6	0.120	2.5	1.71	1.74	9.76	14.74	5.9	1.56	0.102	1.75	8.40	13.01	5.2
420	107.0	98.4	105.2	0.117	2.5	1.66	1.69	10.10	15.11	6.0	1.52	0.099	1.70	8.69	13.33	5.3
450	110.0	101.2	108.4	0.100	2.5	1.43	1.45	10.42	15.21	6.1	1.30	0.085	1.46	8.96	13.36	5.3
480	112.3	103.3	111.1	0.077	2.5	1.09	1.11	10.67	15.10	6.0	1.00	0.065	1.12	9.18	13.20	5.3
510	114.2	105.1	113.2	0.063	2.5	1.90	0.92	10.87	15.11	6.0	0.82	0.054	0.93	9.35	13.18	5.3
540	116.0	106.7	115.0	0.060	2.5	0.86	0.87	11.05	15.28	6.1	0.78	0.051	0.88	9.51	13.31	5.3
570	118.6	109.1	117.2	0.087	2.5	1.24	1.26	11.26	16.04	6.4	1.13	0.074	1.27	9.69	14.04	5.6
600	120.3	110.7	119.4	0.057	2.5	0.81	0.82	11.47	15.75	6.3	0.74	0.048	0.83	9.87	13.71	5.5

METHOD A: Combined arginine retention was used and requirements for maintenance were calculated to according 0.096 g/kg EBW.

METHOD B: Arginine retention in feathers and body arginine was calculated seperately and requirements for maintenance were calculated using mature defeathered arginine weight and mean defeathered arginine weight.

TABLE 11: ESTIMATION OF THE VALINE REQUIREMENTS FOR MAINTENANCE (VAL_m) AND GROWTH (VAL_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL VAL GAIN	G/DAY REQUIRED VAL INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE VAL INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED VAL INTAKE	G/KG DIETARY VAL LEVELS	G/DAY DEFEATHERED BODY VAL GAIN	G/DAY FEATHER VAL GAIN	G/DAY REQUIRED VAL INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE VAL INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED VAL INTAKE	G/KG DIETARY VAL LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	0.92	1.31	0.12	1.66	6.79	0.82	0.14	1.36	0.14	1.74	7.1
60	11.0	9.1	6.6	0.233	0.49	2.05	2.92	0.43	3.89	7.93	1.82	0.30	3.02	0.51	4.10	8.4
90	19.5	16.6	14.6	0.283	0.75	2.49	3.55	0.95	5.22	6.96	2.21	0.37	3.67	1.12	5.56	7.4
120	28.5	25.0	23.6	0.300	0.91	2.64	3.75	1.53	6.13	6.74	2.34	0.39	3.89	1.81	6.61	7.3
150	39.5	36.2	33.6	0.367	1.35	3.22	4.59	2.18	7.85	5.82	2.86	0.48	4.75	2.57	8.50	6.3
180	52.1	47.9	45.4	0.420	1.65	3.69	5.26	2.95	9.52	5.77	3.27	0.55	5.44	3.48	10.35	6.3
210	63.4	58.3	57.5	0.375	1.81	3.29	4.69	3.73	9.78	5.40	2.92	0.49	4.86	4.41	10.75	5.9
240	73.3	67.4	68.1	0.330	1.9	2.90	4.13	4.43	9.93	5.22	2.57	0.43	4.28	5.23	11.02	5.8
270	82.4	75.8	77.6	0.305	1.95	2.68	3.82	5.05	10.29	5.27	2.38	0.40	3.95	5.96	11.50	5.9
300	91.0	83.7	86.5	0.287	2.0	2.52	3.59	5.63	10.69	5.35	2.24	0.37	3.72	6.64	12.02	6.0
330	96.3	88.6	93.6	0.177	2.4	1.55	2.21	6.08	9.62	4.01	1.38	0.23	2.29	7.18	10.99	4.6
360	99.9	91.9	98.0	0.120	2.45	1.05	1.50	6.38	9.14	3.73	0.94	0.16	1.56	7.52	10.53	4.3
390	103.5	95.2	101.6	0.120	2.5	1.05	1.50	6.61	9.41	3.76	0.94	0.16	1.56	7.80	10.85	4.3
420	107.0	98.4	105.2	0.117	2.5	1.02	1.46	6.84	9.63	3.85	0.91	0.15	1.51	8.07	11.12	4.4
450	110.0	101.2	108.4	0.100	2.5	0.88	1.25	7.05	9.63	3.85	0.78	0.13	1.30	8.32	11.16	4.5
480	112.3	103.3	111.1	0.077	2.5	0.67	0.96	7.22	9.49	3.80	0.60	0.10	0.99	8.53	11.04	4.4
510	114.2	105.1	113.2	0.063	2.5	0.56	0.79	7.36	9.46	3.78	0.49	0.08	0.82	8.69	11.03	4.4
540	116.0	106.7	115.0	0.060	2.5	0.53	0.75	7.48	9.55	3.82	0.47	0.08	0.78	8.83	11.14	4.5
570	118.6	109.1	117.2	0.087	2.5	0.76	1.08	7.62	10.10	4.04	0.68	0.11	1.12	9.00	11.74	4.7
600	120.3	110.7	119.4	0.057	2.5	0.50	0.71	7.76	9.83	3.93	0.44	0.07	0.73	9.16	11.48	4.6

METHOD A: Combined valine retention was used and requirements for maintenance were calculated to according 0.065 g/kg EBW.

METHOD B: Valine retention in feathers and body valine was calculated seperately and requirements for maintenance were calculated using mature defeathered valine weight and mean defeathered valine weight.

TABLE 12: ESTIMATION OF THE PHENYLALANINE REQUIREMENTS FOR MAINTENANCE (PHE_m) AND GROWTH (PHE_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL PHE GAIN	G/DAY REQUIRED PHE INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE PHE INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED PHE INTAKE	G/KG DIETARY PHE LEVELS	G/DAY DEFEATHERED BODY PHE GAIN	G/DAY FEATHER PHE GAIN	G/DAY REQUIRED PHE INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE PHE INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED PHE INTAKE	G/KG DIETARY PHE LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	0.94	1.44	0.13	1.93	7.89	0.86	0.06	1.40	0.13	1.88	7.7
60	11.0	9.1	6.6	0.233	0.49	2.09	3.20	0.45	4.51	9.20	1.91	0.12	3.10	0.46	4.40	9.0
90	19.5	16.6	14.6	0.283	0.75	2.54	3.88	1.00	6.03	8.04	2.32	0.15	3.77	1.01	5.91	7.9
120	28.5	25.0	23.6	0.300	0.91	2.69	4.11	1.60	7.06	7.76	2.45	0.16	3.99	1.62	6.94	7.6
150	39.5	36.2	33.6	0.367	1.35	3.29	5.02	2.28	9.03	6.69	3.00	0.19	4.88	2.31	8.89	6.6
180	52.1	47.9	45.4	0.420	1.65	3.76	5.75	3.08	10.93	6.62	3.43	0.22	5.59	3.12	10.77	6.5
210	63.4	58.3	57.5	0.375	1.81	3.36	5.14	3.91	11.18	6.18	3.06	0.20	4.99	3.96	11.06	6.1
240	73.3	67.4	68.1	0.330	1.9	2.96	4.52	4.63	11.31	5.95	2.70	0.18	4.39	4.69	11.23	5.9
270	82.4	75.8	77.6	0.305	1.95	2.73	4.18	5.28	11.70	6.00	2.49	0.16	4.06	5.35	11.63	6.0
300	91.0	83.7	86.5	0.287	2.0	2.57	3.93	5.89	12.13	6.07	2.34	0.15	3.81	5.96	12.09	6.0
330	96.3	88.6	93.6	0.177	2.4	1.58	2.42	6.37	10.86	4.53	1.44	0.09	2.35	6.45	10.88	4.5
360	99.9	91.9	98.0	0.120	2.45	1.08	1.64	6.67	10.28	4.19	0.98	0.06	1.60	6.76	10.32	4.2
390	103.5	95.2	101.6	0.120	2.5	1.08	1.64	6.91	10.58	4.23	0.98	0.06	1.60	7.00	10.63	4.3
420	107.0	98.4	105.2	0.117	2.5	1.05	1.60	7.16	10.82	4.33	0.95	0.06	1.55	7.25	10.88	4.4
450	110.0	101.2	108.4	0.100	2.5	0.90	1.37	7.38	10.81	4.32	0.82	0.05	1.33	7.47	10.88	4.4
480	112.3	103.3	111.1	0.077	2.5	0.69	1.05	7.56	10.64	4.26	0.63	0.04	1.02	7.66	10.72	4.3
510	114.2	105.1	113.2	0.063	2.5	0.57	0.87	7.70	10.59	4.24	0.52	0.03	0.84	7.80	10.68	4.3
540	116.0	106.7	115.0	0.060	2.5	0.54	0.82	7.83	10.69	4.28	0.49	0.03	0.80	7.93	10.79	4.3
570	118.6	109.1	117.2	0.087	2.5	0.78	1.19	7.98	11.33	4.53	0.71	0.05	1.15	8.08	11.41	4.6
600	120.3	110.7	119.4	0.057	2.5	0.51	0.78	8.12	11.00	4.40	0.46	0.03	0.75	8.23	11.10	4.4

METHOD A: Combined phenylalanine retention was used and requirements for maintenance were calculated to according 0.068 g/kg EBW.

METHOD B: Phenylalanine retention in feathers and body phenylalanine was calculated seperately and requirements for maintenance were calculated using mature defeathered phenylalanine weight and mean defeathered phenylalanine weight.

TABLE 13: ESTIMATION OF THE HISTIDINE REQUIREMENTS FOR MAINTENANCE (HIS_m) AND GROWTH (HIS_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL HIS GAIN	G/DAY REQUIRED HIS INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE HIS INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED HIS INTAKE	G/KG DIETARY HIS LEVELS	G/DAY DEFEATHERED BODY HIS GAIN	G/DAY FEATHER HIS GAIN	G/DAY REQUIRED HIS INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE HIS INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED HIS INTAKE	G/KG DIETARY HIS LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	0.57	0.65	0.09	0.86	3.52	0.53	0.011	0.61	0.07	0.80	3.3
60	11.0	9.1	6.6	0.233	0.49	1.27	1.44	0.45	2.22	4.53	1.17	0.025	1.36	0.25	1.88	3.8
90	19.5	16.6	14.6	0.283	0.75	1.54	1.75	1.00	3.22	4.29	1.42	0.030	1.65	0.55	2.57	3.4
120	28.5	25.0	23.6	0.300	0.91	1.63	1.86	1.60	4.05	4.45	1.50	0.032	1.75	0.88	3.08	3.4
150	39.5	36.2	33.6	0.367	1.35	1.99	2.27	2.28	5.33	3.95	1.83	0.039	2.14	1.25	3.97	2.9
180	52.1	47.9	45.4	0.420	1.65	2.28	2.60	3.08	6.66	4.03	2.10	0.045	2.45	1.69	4.85	2.9
210	63.4	58.3	57.5	0.375	1.81	2.04	2.32	3.91	7.29	4.03	1.88	0.040	2.19	2.14	5.07	2.8
240	73.3	67.4	68.1	0.330	1.9	1.79	2.04	4.63	7.82	4.11	1.65	0.035	1.92	2.54	5.23	2.8
270	82.4	75.8	77.6	0.305	1.95	1.66	1.89	5.28	8.40	4.31	1.53	0.033	1.78	2.90	5.47	2.8
300	91.0	83.7	86.5	0.287	2.0	1.56	1.77	5.89	8.97	4.49	1.43	0.031	1.67	3.23	5.74	2.9
330	96.3	88.6	93.6	0.177	2.4	0.96	1.09	6.37	8.73	3.64	0.88	0.019	1.03	3.49	5.29	2.2
360	99.9	91.9	98.0	0.120	2.45	0.65	0.74	6.67	8.68	3.54	0.60	0.013	0.70	3.66	5.10	2.1
390	103.5	95.2	101.6	0.120	2.5	0.65	0.74	6.91	8.97	3.59	0.60	0.013	0.70	3.79	5.26	2.1
420	107.0	98.4	105.2	0.117	2.5	0.63	0.72	7.16	9.22	3.69	0.58	0.013	0.68	3.92	5.39	2.2
450	110.0	101.2	108.4	0.100	2.5	0.54	0.62	7.38	9.36	3.75	0.50	0.011	0.58	4.04	5.42	2.2
480	112.3	103.3	111.1	0.077	2.5	0.42	0.47	7.56	9.41	3.76	0.38	0.008	0.45	4.14	5.37	2.1
510	114.2	105.1	113.2	0.063	2.5	0.34	0.39	7.70	9.48	3.79	0.32	0.007	0.37	4.22	5.38	2.2
540	116.0	106.7	115.0	0.060	2.5	0.33	0.37	7.83	9.60	3.84	0.30	0.006	0.35	4.29	5.43	2.2
570	118.6	109.1	117.2	0.087	2.5	0.47	0.54	7.98	9.97	3.99	0.43	0.009	0.51	4.37	5.71	2.3
600	120.3	110.7	119.4	0.057	2.5	0.31	0.35	8.12	9.92	3.97	0.28	0.006	0.33	4.45	5.60	2.2

METHOD A: Combined histidine retention was used and requirements for maintenance were calculated to according 0.047 g/kg EBW.

METHOD B: Histidine retention in feathers and body histidine was calculated seperately and requirements for maintenance were calculated using mature defeathered histidine weight and mean defeathered histidine weight.

TABLE 14: ESTIMATION OF THE TYROSINE REQUIREMENTS FOR MAINTENANCE (TYR_m) AND GROWTH (TYR_g) FOR OSTRICHES IN VARIOUS GROWTH INTERVALS

METHOD A											METHOD B					
DAYS AGE	KG BODY WEIGHT	KG EMPTY BODY WEIGHT	MEAN PERIOD WEIGHT	KG/B/D ADG	KG/B/DAY AS IS FEED INTAKE	G/DAY TOTAL TYR GAIN	G/DAY REQUIRED TYR INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE TYR INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED TYR INTAKE	G/KG DIETARY TYR LEVELS	G/DAY DEFEATHERED BODY TYR GAIN	G/DAY FEATHER TYR GAIN	G/DAY REQUIRED TYR INTAKE FOR GROWTH	G/DAY REQUIRED DIGESTIBLE TYR INTAKE FOR MAINT.	G/DAY TOTAL REQUIRED TYR INTAKE	G/KG DIETARY TYR LEVELS
DAYOLD	0.85	0.8														
30	4.0	3.3	1.8	0.105	0.245	0.65	0.72	0.09	1.00	4.06	0.59	0.051	0.71	0.08	0.96	3.9
60	11.0	9.1	6.6	0.233	0.49	1.44	1.60	0.34	2.37	4.84	1.31	0.113	1.57	0.28	2.26	4.6
90	19.5	16.6	14.6	0.283	0.75	1.75	1.94	0.75	3.29	4.39	1.59	0.137	1.91	0.61	3.09	4.1
120	28.5	25.0	23.6	0.300	0.91	1.86	2.05	1.20	3.99	4.38	1.68	0.145	2.02	0.98	3.68	4.0
150	39.5	36.2	33.6	0.367	1.35	2.27	2.51	1.71	5.17	3.83	2.06	0.177	2.47	1.39	4.74	3.5
180	52.1	47.9	45.4	0.420	1.65	2.60	2.87	2.31	6.36	3.85	2.36	0.203	2.83	1.88	5.78	3.5
210	63.4	58.3	57.5	0.375	1.81	2.32	2.57	2.93	6.73	3.72	2.10	0.181	2.53	2.39	6.02	3.3
240	73.3	67.4	68.1	0.330	1.9	2.04	2.26	3.47	7.02	3.70	1.85	0.159	2.22	2.83	6.19	3.3
270	82.4	75.8	77.6	0.305	1.95	1.89	2.09	3.96	7.41	3.80	1.71	0.147	2.06	3.23	6.47	3.3
300	91.0	83.7	86.5	0.287	2.0	1.77	1.96	4.42	7.82	3.91	1.61	0.138	1.93	3.60	6.77	3.4
330	96.3	88.6	93.6	0.177	2.4	1.09	1.21	4.77	7.33	3.05	0.99	0.085	1.19	3.89	6.22	2.6
360	99.9	91.9	98.0	0.120	2.45	0.74	0.82	5.00	7.14	2.91	0.67	0.058	0.81	4.07	5.98	2.4
390	103.5	95.2	101.6	0.120	2.5	0.74	0.82	5.19	7.36	2.94	0.67	0.058	0.81	4.22	6.17	2.5
420	107.0	98.4	105.2	0.117	2.5	0.72	0.80	5.37	7.57	3.02	0.65	0.056	0.79	4.37	6.32	2.5
450	110.0	101.2	108.4	0.100	2.5	0.62	0.68	5.53	7.62	3.05	0.56	0.048	0.67	4.51	6.35	2.5
480	112.3	103.3	111.1	0.077	2.5	0.47	0.52	5.67	7.59	3.04	0.43	0.037	0.52	4.62	6.29	2.5
510	114.2	105.1	113.2	0.063	2.5	0.39	0.43	5.78	7.61	3.04	0.36	0.031	0.43	4.70	6.29	2.5
540	116.0	106.7	115.0	0.060	2.5	0.37	0.41	5.87	7.70	3.08	0.34	0.029	0.40	4.78	6.35	2.5
570	118.6	109.1	117.2	0.087	2.5	0.54	0.59	5.98	8.06	3.22	0.49	0.042	0.58	4.87	6.68	2.7
600	120.3	110.7	119.4	0.057	2.5	0.35	0.39	6.09	7.94	3.18	0.32	0.027	0.38	4.96	6.55	2.6

METHOD A: Combined tyrosine retention were used and requirements for maintenance were calculated to according 0.051 g/kg EBW.

METHOD B: Tyrosine retention in feathers and body tyrosine was calculated seperately and requirements for maintenance were calculated using mature defeathered tyrosine weight and mean defeathered tyrosine weight.